PRINCIPLES AND PRACTICE OF FILLING TEETH WITH PORCELAIN

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Principles and Practice *of* Filling Teeth with Porcelain

With 132 Illustrations

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TO MY BELOVED ASSOCIATE
DR. GEORGE EDWIN HUNT
IN RECOGNITION OF HIS FRIENDSHIP
THIS BOOK IS RESPECTFULLY
INSCRIBED BY THE
AUTHOR.

Preface.

IN PRESENTING this treatise on filling teeth with porcelain, the author does it because he believes it to be the best material for filling cavities in incisors and cuspids. No material known to dentistry presents such artistic possibilities, and the primary cause of failure is largely due to the fact that many dentists have treated this artistic work purely as a mechanical operation. The mechanical side of the operation must not be lost sight of, and the many points of mechanical detail must be carefully executed to make the operation successful.

Literature in connection with porcelain has been much in evidence, and it would seem that the subject has been thoroughly covered. However, there has been but little practical information to the beginner in it. The "high fusing" enthusiast could see no virtues in "low fusing" porcelain, and the "low fusing" enthusiast attributed his success to the material used. Each manufacturer claimed to have the best product and so played upon the credulity of the inexperienced that many sore disappointments were caused.

Porcelain will hold its place as a filling material, and every conscientious dentist should use it when it is indicated. The practice of disfiguring patients by filling conspicuous cavities with gold should be discontinued, for he who uses good judgment in the selection of filling materials serves his patients best.

JOHN Q. BYRAM, D.D.S.

Contents.

CHAPTER I.

Porcelain in Operative Dentistry 9

CHAPTER II.

Preparation of Cavities 23
Instruments. Cavities on Labial and Buccal Surfaces. Approximal Cavities in Incisors and Cuspids; Approximo-labial Cavities; Approximo-lingual Cavities; Labio-lingual Cavities; Approximal Cavities with Step Formation.

CHAPTER III.

Preparation of Cavities 34
Approximo-Incisal Cavities; Formation Without Step; Formation With Step. Mesio-disto-incisal Cavities. Cavities Involving Incisal Edge. Teeth Affected by Malformation and Erosion. Cavities in Bicuspids and Molars.

CHAPTER IV.

The Formation of Matrices for Porcelain Inlays 59
Matrix Materials. Methods of Constructing. Technique of Burnishing. Impression Methods. Models of Cavities; Amalgam; Cement. Devices and Methods of Swaging. Refitting Matrices.

CHAPTER V.

Some Phenomena of Color in Porcelain Inlay Work 79

CHAPTER VI.

The Selection and Application of Porcelain 89
Building in Layers. Building in Sections. Mixing Colors. Technique of Applying Porcelain to the Matrix.

CHAPTER VII.

Technique of Fusing Porcelain—Furnaces and Pyrometers ... 102

CHAPTER VIII.

Technique of Finishing and Setting Inlays 116

The Principles and Practice of Filling Teeth with Porcelain.

Chapter I.

Porcelain in Operative Dentistry.

In endeavoring to present "The Principles of Filling Teeth with Porcelain," the author realizes that many methods of performing operations are transient. The desire to give to our patients the best at our command necessitates changes, so the practice of to-day may be improved to-morrow. Operations are dependent, in a measure, upon the individuality of the operator, and that method which may be most successful with one dentist may be inadequate with others.

Before proceeding further, the author wishes to acknowledge the work of all who have earnestly labored for the development of porcelain art in dentistry. The many suggestions received from his confreres have been invaluable to him, and it is with their assistance that he attempts this work. He claims no originality, but desires to give a compilation of that which seems to be best from the writings of many of the ablest porcelain workers.

The problem of aborting or abating caries of the teeth, is one that always has, and always will confront the dentist; and until we are able to prevent dental caries, our principal work will be to check it. In order that caries may be abated to the greatest possible extent, it is necessary that the affected portion of the tooth be removed and replaced with a substitute. There has been a desire on the part of many to find a substitute material that would satisfy the esthetic sense by simulating the natural tooth, while also affording permanency of the operation. That desire has found frequent expression and experiments have been made with a number of materials; the two that have received the most attention have been cement and porcelain. As the former has so far failed to fulfill more requirements than the latter, our efforts are best directed in perfecting the methods of filling teeth with porcelain.

Porcelain as a Filling Material.

While porcelain seems to present hygienic advantages, along with its cosmetic values, it is by no means a prophylactic filling, and unless prophylaxis is practiced by both dentist and patient, many good fillings will fail. It is essential that the patient should keep the mouth as nearly hygienic as possible, and that the dentist should utilize prophylactic measures during the operations.

The art of filling teeth with porcelain is comparatively new, and it may be said that it is still in a developmental stage. Porcelain as applied to the dental art prior to 1885 was practically confined to the manufacture of teeth, crowns, and rods used as "cavity stoppers," and the construction of continuous gum dentures. About this time a method of constructing glass fillings by fusing powdered glass into positive molds of the cavity, constructed of an investment material, was introduced in Europe. Shortly afterward inlays were produced in America, by burnishing matrices into the cavities and fusing porcelain into them. By the untiring efforts of a few dentists in various sections of America and Europe, the subject of porcelain as a filling material has been kept before the profession.

Too much credit can not be awarded the pioneers of porcelain inlay work, and we wish to pay our tribute to all those gentlemen, through whose untiring efforts, and perseverance, it is possible for us to accomplish such artistic results. The stimulus engendered by the efforts of these earnest workers, resulted in the development of this art to a higher standard and caused others to begin studying the advantages of this material; so in 1900 a wave of enthusiasm burst forth from all parts of the globe, and now the methods of filling teeth with porcelain are familiar to many dentists. This advancement was made possible, in a measure, by the increased facilities and improved products furnished by the manufacturers.

It is true that the application of porcelain has been indiscriminately and injudiciously employed. This has resulted from over enthusiasm on the part of a few, and ignorance of the properties of porcelain and the principles of inlay work on the part of many.

Porcelain inlays have passed the experimental stage, and their value as cosmetic fillings is more universally recognized.

The beginner should comprehend that a good porcelain inlay worker must have a keen observation; a thorough knowledge of the principles of inlay work and of the properties of porcelain; a mastery of the technique and a knowledge of the principles of color formation, with the eye trained to detect the delicate hues of a color. While it is desirable to have a thorough theoretic knowledge of porcelain inlays, it is impossible, however, to perform operations in this branch of dental art, without proper technical training.

That we may be better acquainted with certain terms used in dental porcelain art, let us consider the following glossary:

Glossary of Technical Terms.

Dental Porcelain. A solidified mass composed of one or more silicious substances suspended in a fused silicate.

Silex. The oxid of silicon, which is a white, highly fusible, moderately hard, crystaline substance.

Kaolin. The hydrated silicate of aluminum, which is white, opaque, refractory clay, resulting from the decomposition of feldspar.

Feldspar (Orthoclase). The silicate of aluminum and potassium with varieties and in which the aluminum is partially replaced by sodium. It is a translucent, moderately high fusing substance, and varies in color.

Fusion. A chemico-physical change produced by subjecting porcelain to enough heat units for a given time to cause a rearrangement of the molecules, with partial vitrification, and a glaze of the surface of the mass.

Firing. The process of heating porcelain in a furnace.

Soft Biscuit. A state resulting from heating porcelain sufficiently to harden it only enough to permit it to be carved.

Hard Biscuit. A state resulting from heating porcelain sufficiently to harden it enough to prevent carving, but yet not enough to produce shrinkage.

High Biscuit. A state resulting from heating porcelain sufficiently to obtain shrinkage, but not enough to produce glaze.

High Fusing Porcelain. A porcelain which requires more than five minutes to fuse at a heat not exceeding 2,000 degrees F.

Low Fusing Porcelain. A porcelain which requires less than five minutes to fuse at a heat not exceeding 2,000 degrees F.

Basal Ingredients. Those ingredients which form the fundamental mass of the porcelain. Viz.: silex, kaolin, and feldspar.

Flux. A material used to increase the fusibility of porcelain.

Pigment. Metals or their oxids which, when added to porcelain and heated to a high degree, will produce a definite hue of color.

Frit. An intense pigment which is fused with feldspar and flux and then ground to a fine powder and used as the coloring material for dental porcelain.

Basal Body. Porcelain composed of the basal ingredients and the pigment. This includes such terms as block body, tooth body, etc.

Foundation Body. A basal body, the fusibility of which has been increased by the addition of a flux, and one which requires more than two minutes to fuse at a temperature of 2,100 degrees F.

Enamel Body. A basal body with enough flux added to give it greater fusibility than that of the foundation body.

Foundation. That portion of an artificial tooth, crown, or inlay, which takes the place of lost dentin.

Enamel. That portion of an artificial tooth, crown, or inlay, which takes the place of the lost enamel.

Glaze. A highly translucent, colorless, vitrifiable substance which, when applied to the surface of porcelain fuses at a lower temperature than the enamel, produces a highly glazed surface.

Platinous Gold. An alloy of gold and platinum containing less than 50 per cent. of platinum.

General Considerations of Porcelain.

In order to understand better the properties of porcelain, it is necessary to consider the ingredients of which it is composed. Such a consideration shows porcelain to be made up of three classes of substances. First, the basal ingredients, which are very refractory; silex and kaolin, which when heated alone, will undergo intense heat with practically no change; and feldspar, a less refractory substance, which when heated to a high degree undergoes liquifaction. Second, fusible substances known as fluxes, which fuse at a lower temperature and increase the fusibility of the more refractory substances; and, third, metals or their oxids used as pigments.

Silex. Silex ($Si\ O_2$) is the oxid of silicon, and is an infusible substance insoluble in all acids except hydrofluoric, but slightly soluble in caustic alkalis. It forms about 13.5 per cent. of the basal mass. It adds strength and firmness to the porcelain and gives it a more translucent appearance.

Kaolin. Kaolin ($2Al_2\ O_3\ Si\ O_2\ 3H_2\ O$) is the silicate of aluminum and is composed of aluminum oxid, silicon oxid and water. It is commonly spoken of as disintegrated feldspar. Through the natural process of decomposition feldspar loses its potassium oxid ($K_2\ O$) by the action of water and other agents. Kaolin forms about 4.5 per cent. of porcelain. It is a very refractory clay when heated alone, but readily unites with feldspar when mixed with it. When added to porcelain it gives stability of form, which property permits unfused porcelain to be molded and carved.

Feldspar. Feldspar ($Al_2 O_3 K_2 O 6Si O_2$) is the double silicate of aluminum and potassium. It is composed of aluminum oxid, potassium oxid and silicon oxid. The chemical difference between feldspar and kaolin is that feldspar contains potassium oxid, which kaolin does not, and kaolin contains water of crystalization, which feldspar does not. It composes about 82 per cent. of the basal mass of porcelain and adds translucency to it. While feldspar is more fusible than either silicon or kaolin, it requires more heat than can be produced in the electric furnace to fuse some grades of it.

Fluxes. The materials commonly used as fluxes, to increase the fusibility of porcelain, are substances containing sodium borate ($Na_2 B_4 O_7$), sodium carbonate ($Na_2 Co_3$), potassium carbonate ($K_2 Co_3$), or glass (which contains the oxids of potassium or sodium). The more refractory ingredients, the flux and the frit are ground together in the preparation of the porcelain for the market. Then, when fused, a chemical change takes place, forming an indefinite compound, from which none of the original ingredients can be removed except by some process which involves the destruction of other ingredients.

Pigments. The pigments most commonly used in the manufacture of dental porcelains are precipitated gold, platinum, purple of Cassius (the oxid of gold and tin), the oxids of gold, titanium, manganese, cobalt, iron, uranium and silver. The colors produced by the use of these pigments in varying proportions are hues of red, yellow, blue, green, brown, and gray.

Dental Porcelain. The basal ingredients of porcelain are used in the formulæ for low fusing porcelains, but the fusibility is regulated by the proportion of flux added to the formula. The process of fusing and grinding is continued until the ingredients are thoroughly mixed. Both high and low fusing porcelains may contain a small proportion of starch in their formulæ, which imparts additional stability of form by agglutinating the particles of the mass during the process of molding and carving. It is not, however, a component ingredient of the porcelain, for the heat required to fuse the porcelain will volatilize the starch.

Dental porcelain is divided into high fusing and low fusing porcelain. The distinction has been accepted by the profession to mean that a high fusing porcelain is one which fuses above the melting point of pure gold, while a low fusing porcelain fuses at a temperature below this point. Such a distinction is relative rather than accurate, because porcelain has no definite fusing point. Any enamel body or foundation

body can be fused on pure gold, provided enough time is given. Some low fusing porcelain will fuse above the fusing point of pure gold, provided the requisite heat to fuse the gold is obtained rapidly. While the above distinction seems to meet all practical requirements, it is unscientific and its only value is to make a convenient distinction between the two classes of porcelain for practical usage.

Because porcelain is an indefinite compound and has no definite fusing point, the following distinction is made between high and low fusing porcelain. High fusing porcelains require more than five minutes to fuse, while low fusing porcelains require less than five minutes to fuse at 2,000 degrees F. It is impossible to fuse any of the high fusing porcelains at 2,000 degrees F. in five minutes, and it is also impossible to keep any of the low fusing porcelains in contact with a heat of 2,000 degrees F. for five minutes without becoming over fused. Porcelains are divided into basal bodies, foundation bodies, enamel bodies and glazes. All basal and foundation bodies are high fusing porcelains, while enamel bodies and glazes may be either high or low fusing porcelain.

Basal bodies are used in crown and bridge-work and for the construction of hand carved teeth, but there is no necessity for using them in inlay work. The use of basal bodies requires a specially constructed furnace for obtaining and maintaining the intense heat needed to fuse them. The present types of electric furnaces may be used, but they can not be depended upon to furnish enough heat to fuse large masses of basal body unless new muffles are procured oftener than most dentists care to buy them, because the intense heat causes the fire clay readily to affect the platinum wire of the muffle. But the foundation and enamel bodies will meet the requirements for inlay work, and the operator should learn the characteristic properties of each of these two classes of porcelain.

While all the porcelains have properties in common, there are, however, certain properties which characterize each manufacturer's product. It is important that these characteristics should be thoroughly understood in order to obtain the best results. With all porcelains the general principles of manipulation are the same. All may be mixed with alcohol, but this mixture is not adapted to molding and carving. Likewise all porcelains may be mixed with water, which insures the possibility of molding and carving.

Laboratory experiments with the various porcelains will prove of great value both to the student and the practitioner. If the characteristic properties of the different porcelains are understood, the selection of the material to meet individual requirements will be simplified and the operator will be relieved of much uneasiness.

Phenomena Met in Fusing Porcelain.

In a series of experiments carried on for the purpose of studying some of the phenomena of the fusing of the various porcelains, cubes of porcelain 5 mm. on each face, weighing approximately 2.5 grains when thoroughly dried, were taken for a standard (Fig. 1). The first experiments were to determine the fusibility of the different porcelains. As porcelains are indefinite compounds, they have no definite fusing point. Porcelains which ordinarily vitrify from 2,080 to 2,500 degrees can be fused on pure gold by allowing long enough time. The experiments showed that Brewster's enamel body can be properly fused on pure gold in from fifteen to forty-five minutes. The difference in time depends upon the heat applied. Close's body (Justi's) requires

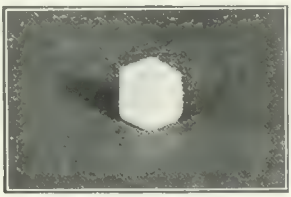


FIG. 1.

from thirty minutes to one hour and fifteen minutes to fuse properly on pure gold. Brewster's foundation body, S. S. White's inlay and Whiteley's inlay porcelains require from one to three hours to fuse on pure gold. The Consolidated Company's high fusing porcelain requires from eight to ten hours to fuse on the same material.

It was found that Brewster's foundation body, Close's body (Justi's), S. S. White's and Whiteley's inlay porcelains could be fused on 10 per cent. platinous gold, which fuses approximately at 2,115 degrees, in from fifteen to thirty minutes. Tests were also made with these porcelains on 15 per cent. platinous gold, which fuses approximately at 2,175 degrees. It then required from ten to twenty minutes to fuse Brewster's foundation body, S. S. White's and Whiteley's inlay porcelains.

In studying fused porcelain under the microscope, it was observed that those porcelains which were fused at a lower temperature for a long time, presented more homogeneous and more highly glazed surfaces, while the surfaces of porcelains which were fused at a high temperature for a short time appeared more granular. The cubes were then fractured and the inner portion examined under the microscope. It was invariably found that those porcelains which were fused for a long time at a lower temperature were more homogeneous in texture.

The next series of experiments were made to determine the relative porosity of underfused and overfused porcelain. In studying the surfaces of the cubes of both high and low fusing porcelains under the microscope, it was found that the surfaces of overfused porcelain were covered with little blisters. Underfused porcelain appeared granular and less dense, while properly fused porcelain presented a denser surface, free from blisters.

The next experiments were to determine the effect of repeated contact of porcelain with the maximum heat required to fuse it. A cube of porcelain was fused at a definite degree of heat. A second cube was then placed beside the first and both heated to the same degree of heat. Then a third cube was placed beside the two and the three heated to the heat required to fuse them. This process was continued until the fifth cube had been fused. The first, second and third cubes were slightly overfused and lighter in color, while the fourth was only slightly lighter in color.

The next experiment was to test the effect of repeated heating of porcelain to the point of biscuiting. This showed that any of the porcelains would finally become fused and maintain their characteristic color.

It is a significant fact that underfused porcelain has a much duller color and is more opaque, while overfused porcelain becomes lighter and tends to become more transparent. If porcelain remains in contact with the maximum heat long enough, it fuses into a glass-like mass. All the shades of a color from a normal to a light may be obtained by increasing the heat above the maximum fusing point of the porcelain, but this is done at a sacrifice of its strength.

It is also a fact that porcelain can be fused, then ground and re-fused at a lower temperature than the first fusing. And if this process of re-fusing and regrinding be repeated a number of times, a high fusing porcelain becomes low fusing. It was also found that the re-fusing and grinding of the porcelain changed its properties.

Deductions from Experiments.

The following deductions are made from these experiments:

1. Porcelain has no definite fusing point.

2. By prolonging the time of exposure to heat, a thoroughly fused porcelain may be obtained at a comparatively low temperature.

3. Porcelains fused at a lower temperature for a long time will maintain their characteristic color, and will be more homogeneous in texture.

4. Low fusing porcelains can be made of high fusing porcelains by repeated fusing and grinding.

5. If a piece of porcelain is thoroughly fused and more porcelain added and fused, the first layer will be slightly overfused. In the process of applying porcelain in layers and fusing each layer, the underlying layers will be slightly overfused and somewhat lighter in color.

6. A small mass of porcelain is more readily affected by heat than a larger one, and as the size of the mass of porcelain increases just in that ratio does the length of time required to fuse it increase.

7. Porcelains containing a large percentage of flux are more easily affected by bubbles than those that are more nearly composed of the basal ingredients.

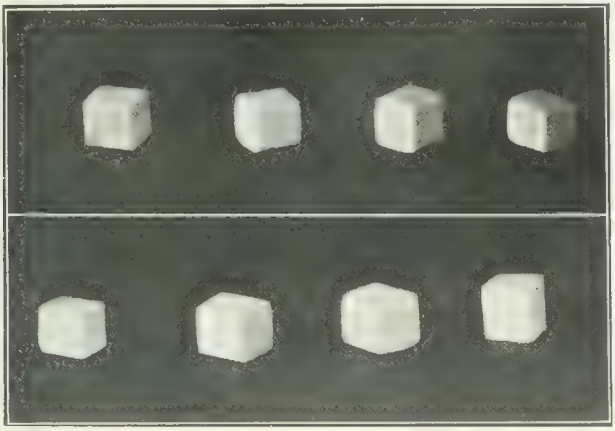


FIG 2.

8. It is more difficult to maintain the characteristic color of low fusing than high fusing porcelains when held for a long time at the maximum heat required to fuse them.

9. Low fusing porcelains are denser, have greater shrinkage and less tensile strength than high fusing porcelains.

10. By repeatedly heating porcelain to the point of high biscuiting, it will finally become fused and maintain its characteristic color.

11. High fusing porcelains shrink from 15 to 25 per cent., while low fusing porcelains shrink from 20 to 35 per cent.

12. A coarsely ground porcelain fuses at a higher temperature and shrinks less than one of the same formula finely ground.

13. The amount of shrinkage of any porcelain will in a measure be dependent upon the consistency to which it is mixed, and the density to which it is condensed. The thin mixtures show more shrinkage than those of a putty-like consistency.

14. Underfused porcelain has a much duller hue and is more opaque, while overfused porcelain becomes lighter and tends to become more transparent. All the shades of a color from dark to a light may be obtained by increasing the heat above the maximum fusing point of the porcelain, but this is done at the sacrifice of its strength.

15. The tendency of both high and low fusing porcelains is to assume spheroidal form when overfused, and if considerably overfused they tend to form an amorphous mass of glass.

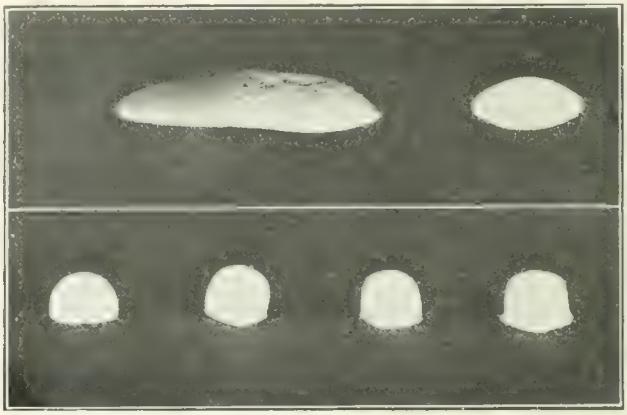


FIG. 3.

Figure 2 shows four cubes of low fusing and four cubes of high fusing porcelain each heated separately to the state of hard biscuit. Figure 3 shows the effect on the form of the mass by overfusing porcelain. All of these cubes were fused at the same time and heated to a degree of heat sufficient to overfuse the foundation bodies.

The first three cubes ran together into an amorphous glass-like mass, while the fourth cube formed an amorphous mass to itself. The fifth cube, which was an enamel body, changed to an irregular spheroidal form and the last three cubes became rounded at the edges.

The process of fusing porcelain is largely a chemical reaction, brought about by the various ingredients combining to form multiple silicates of aluminum, potassium or sodium with the liberation of gases.

The method of fusing porcelain at its maximum temperature for a short time is to be condemned. It makes the porcelain more brittle and causes the formation of minute bubbles throughout the entire mass, for

the intense heat required to fuse the porcelain in a short time may cause the generation of gas faster than it can escape.

The pioneers of dentistry who began the development of dental porcelain were more skillful in its manipulation than most of us at the present time. They were required to grind their materials, solve their formulæ and compound their ingredients. They were also required to carve gum section blocks and other special forms of teeth, and thus developed an art that is almost lost to the dental profession to-day. The technique of performing experimental operations with porcelain develops the operator's skill in its manipulation and thus assists him in performing his practical operations. Experimental work in the laboratory is not a waste of time, but helps one to become more familiar with the subject. The difficulty with many beginners is their unwillingness to devote that time to experimental work which is required to obtain a thorough knowledge of the properties of porcelain and the general principles of manipulating it.

Advantages and Disadvantages. Indications and Contra-Indications of Porcelain Inlays.

Before studying the methods of constructing porcelain inlays, let us consider their advantages and disadvantages, their indications and contra-indications.

The advantages of porcelain as a filling material are:

1. Fillings can be inserted which more nearly harmonize with the natural teeth.

2. Porcelain is a poor conductor of thermal and a non-conductor of electrical changes.

3. The margins of cavities properly filled with porcelain, are not readily attacked by caries.

4. The cement used as a retaining medium causes the filling to have the greatest adhesion of any of the filling materials except cement.

5. The patient is relieved of sitting with the rubber dam adjusted over the mouth for periods of considerable length, and of the pain incident to adjusting the rubber dam and cervical clamps for cavities extending beneath the gum.

6. The nervous strain of both patient and dentist is lessened, thereby relieving the patient of the shock which usually follows long, tedious operations.

7. Busy patients need not spend so much time in the dental chair. After the cavity is prepared the matrix may be burnished to the cavity, or an impression of the cavity may be taken, and then the patient dismissed until the inlay is completed.

8. Faulty fillings are easily dislodged. While porcelain has the advantage over gold in making a filling that more nearly harmonizes with the natural teeth, and one that is a non-conductor of thermal and electrical changes, it has still another advantage, which should appeal to all conscientious operators, in that imperfect fillings made of this material are easily dislodged. A large number of faulty gold fillings, which do not preserve the teeth, are retained by deep grooves, so that it is almost impossible to dislodge them; such fillings deceive the patient, and many times even the dentist. If a porcelain filling is faulty, it is displaced, and the patient knows immediately that the services of a dentist are required.

Disadvantages of Porcelain.

The disadvantages of porcelain as a filling material are:

1. The friability of porcelain causes it to fracture readily, thereby excluding it from any form of cavity that can not be so prepared that frail margins of the filling material can be avoided or else protected from stress.

2. It is impossible to bevel the cavity margins to protect the enamel. The relative strength of the porcelain and the enamel are approximately the same so that one can not protect the other.

3. It is difficult to match the color of the natural teeth. This always has been and always will be one of the most serious disadvantages of porcelain as a filling material; and until we understand more thoroughly the general phenomena of color formation, we may expect to be disappointed with many of our inlays.

4. The cement used as a retaining material may cause a change in the color of the tooth or of the inlay. This, however, may be largely overcome by the application of correct principles in cavity preparation.

5. The cement will dissolve unless there is only a thin film used as the retaining medium. This is not so much a disadvantage to the skilful, painstaking operator; for, if the margins are defective, he will remove the defect by making a new inlay. But to the incompetent or careless operator, this will always be a disadvantage, because any cement now produced will dissolve from the margins of an ill-fitting inlay.

Applicability of Porcelain.

Porcelain is not applicable to all forms of fillings, and it will never entirely displace gold or amalgam as filling materials. It has taken its place, however, along with these materials, and, when properly applied and judiciously used where indicated, porcelain should

even take first rank as a filling material. Its indications as a filling material may be classified, first, as general, and second, as local. The following will be considered under the first classification:

1. For those patients who really have an appreciation of the esthetic quality of dental operations, and who object to the conspicuousness of metallic fillings. Many patients fancy that they appreciate this quality, but they measure their appreciation rather by the cost and permanency of the work than by an esthetic standard.

2. For those patients whose physical condition is such that the insertion of a large gold filling would give rise to a nervous shock. We should consider the effect of such shock on the system and endeavor to avoid subjecting our patients to long, tedious and painful operations.

3. For those patients whose pericementum and alveolar process are diseased, a condition which almost excludes any material that requires considerable condensation.

4. For those patients who are suffering from caries that has progressed to such an extent that the pulp is almost involved, and in whose teeth the pulp would die, if filled with gold, because of the irritation caused by thermal changes.

The indications under the second classification are:

1. All cavities on the labial and very many on the buccal surfaces of teeth.

2. Some simple approximal cavities on incisors and cuspids.

3. Approximo-incisal cavities, if these cavities can be prepared in such a manner that the retentive resistance will be greater than the stress.

4. Cavities involving the incisal edge.

5. Approximo-occlusal cavities on bicuspids and molars in which the cavities are so prepared that a large enough mass of porcelain may be used to withstand the stress applied, and in which the frail margins will not be exposed to the stress of mastication, or in which the cavity extends far beneath the gingival margin.

6. Deep cavities on the occlusal surface of lower molars.

7. Cavities involving the entire occlusal surface of pulpless molars.

Contra-Indications. The choice of porcelain is contra-indicated in the following conditions:

1. In those cavities from which the stress will dislodge the filling or cause it to fracture.

2. In those simple approximal cavities on incisors and cuspids in which a gold filling is scarcely noticeable.

3. In disto-occlusal cavities of upper bicuspids and molars.

4. In nearly all occlusal cavities in upper molars and those occlusal cavities in lower molars in which severe usage in the process of mastication might cause the margins of the inlay to fracture.

While porcelain may be used as a material for filling many cavities in bicuspids and molars with a fair degree of success, it has nevertheless been demonstrated that it is not the safest material to use for filling most of the cavities in these teeth. It should be chosen, therefore, only where the requirements demand it for filling cavities in bicuspids and molars. The dentist who limits his practice to filling cavities in incisors and cuspids with porcelain will probably render his patients better service than the one who promiscuously inserts inlays in all classes of cavities regardless of their indications and contra-indications.

Generally speaking, as the size of the cavities in *vital* incisors and cuspids increases does the indication for porcelain inlays also increase, for if a small gold filling at the gingival margin of an incisor or a cuspid is conspicuous, such a filling in an approximo-incisal cavity is much more noticeable. While there is a limit to the size of a porcelain inlay that may be inserted in an approximo-incisal cavity successfully, there are, nevertheless, too many crowns adjusted upon incisors and cuspids. The comparative ease with which a crown may be adjusted upon these teeth induces many operators to overlook the good qualities of porcelain as a filling material for many large cavities. On the other hand, the decision as to whether an inlay shall be inserted into a particular cavity should be dependent upon the degree of the operator's skill. The prudent operator will not attempt to insert large approximo-incisal inlays, for example, until he has become thoroughly familiar with the methods of cavity preparation and is a master, in a very large degree, of the technique of inlay construction; for the construction of porcelain inlays involves a series of mechanical principles, which must be observed with precision. Failure to apply these principles will cause imperfect fillings. The best work can be accomplished only when the operator possesses a through knowledge of the principles of inlay construction, of the properties of porcelain, a mastery of inlay technique, and when the eye is trained to detect the delicate hues of colors.

Chapter II.

Preparation of Cavities.

Instruments. Cavities on Labial and Buccal Surfaces. Approximal Cavities in Incisors and Cuspids; Approximo-labial Cavities; Approximo-lingual Cavities; Labio-lingual Cavities. Approximal Cavities with Step Formation.

It is essential that the beginner in inlay work should understand the principles of cavity preparation. Disregarding this foundation work, many dentists have become discouraged, because they began to construct inlays for practical cases before they had studied these principles. The change in the method of cavity formation is not a difficult one, even though the operator has been preparing cavities for gold and amalgam fillings for a long time, provided he understands thoroughly the principles of retention for the different fillings.

The preparation of many cavities for inlays requires the sacrifice of sound tooth structure in order to secure the necessary retentive resistance, to prevent frail margins of porcelain, and to obtain proper color effects. In many instances it has been found that more sound tooth structure is involved in the preparation of the cavity for an inlay than for gold filling. All frail enamel should be removed. Most porcelain workers agree that the cavity should be prepared so that the inlay will have all the retentive resistance possible; that parallel walls in cavities are to be avoided, and that the walls should diverge slightly toward the margin instead of converging. It should be borne in mind that porcelain is a friable material, and that its strength is approximately equal to that of enamel. These facts are frequently disregarded, and the cavity is not prepared with the view to making the inlay as strong as possible. Too often carelessness in cavity preparation is the cause of weak margins of porcelain, and these, in turn, render the filling imperfect. In such cases there is a tendency to attribute the imperfection of the filling to the material used rather than to the method employed.

In illustrating cavity preparation with drawings and photographs of plaster models of teeth, it must be borne in mind that cavities pre-

pared in such models are diagramatic, and that they are only intended to illustrate principles. An attempt will be made to give examples of the various forms of cavity preparation used in filling teeth with porcelain. Many of these forms may appear to involve the sacrifice of an unnecessary proportion of tooth structure, but such sacrifice insures better retentive resistance and a stronger mass of porcelain.

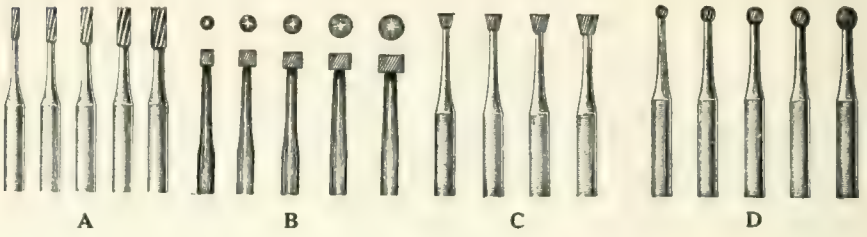


FIG. 4.

Instruments.

The preparation of cavities for porcelain inlays requires but few special instruments. Figs. 4 and 5 represent the forms of burs and stones that are particularly indicated in this work. These instruments should be obtained for both the straight and the angle hand piece.

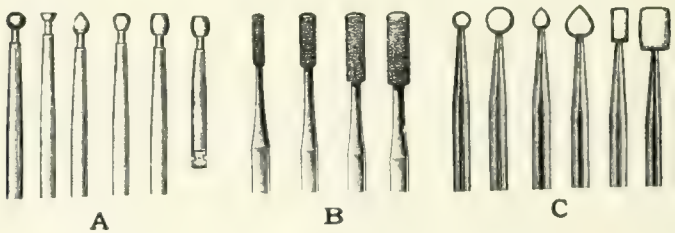


FIG. 5.

Fig. 4, A, represents the regular forms of flat faced fissure burs. Fig. 4, B, C and D, represent finishing burs, cylindrical, inverted cone and round in form. These burs are useful in shaping and finishing the walls and margins of cavities.

Fig. 5, A and B, represent cavity trimmers and diamond burs. They are useful in cutting away enamel and shaping cavities. The grit is fine and they leave the surface smooth.

Fig. 5, C, represents different shapes of Arkansas stones that may be used in finishing the margins and cavities. It is not intended that they be used for grinding to any considerable extent, but to polish the margins.

Fig. 6 shows two forms of hoe excavators that are useful in shaping the walls of cavities and giving to them definite angles. A represents that form which is useful in shaping the gingival wall, while B represents the form that is useful in shaping the axial walls.

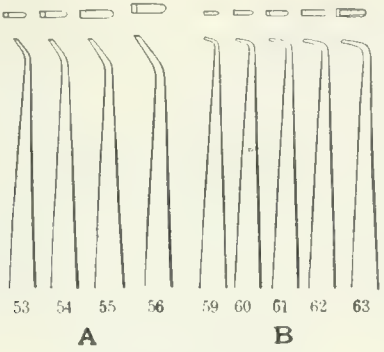


FIG. 6.

Cavities on the Labial and Buccal Surfaces.

Forcing the Gum from the Cavity.

If the cavity extend beneath the gum margin, the gum should be forced from the cavity with base plate gutta percha. The gingival and approximal walls should be prepared with an inverted cone bur so that they form a slight undercut. The gutta percha should be packed in such manner that sufficient pressure to cause the gum to recede will be made upon it so that it will not interfere with the preparation of the gingival margin. In case it is inadvisable to form undercuts in any of the walls of the cavity, the gutta percha should be packed tightly into the cavity and secured with a silk ligature.

Marginal Outlines.

While cavities on the labial surfaces of many teeth are usually found in the gingival region, they occur also in the middle and incisal thirds of the labial surfaces of many teeth. Cavities on the labial and buccal surfaces of teeth usually assume some of the forms shown in Figs. 7 and 8. The circular form is usually found in the middle and incisal thirds of teeth. In the preparation of most cavities in the gingival region on these surfaces, the other forms of marginal outline should be used.

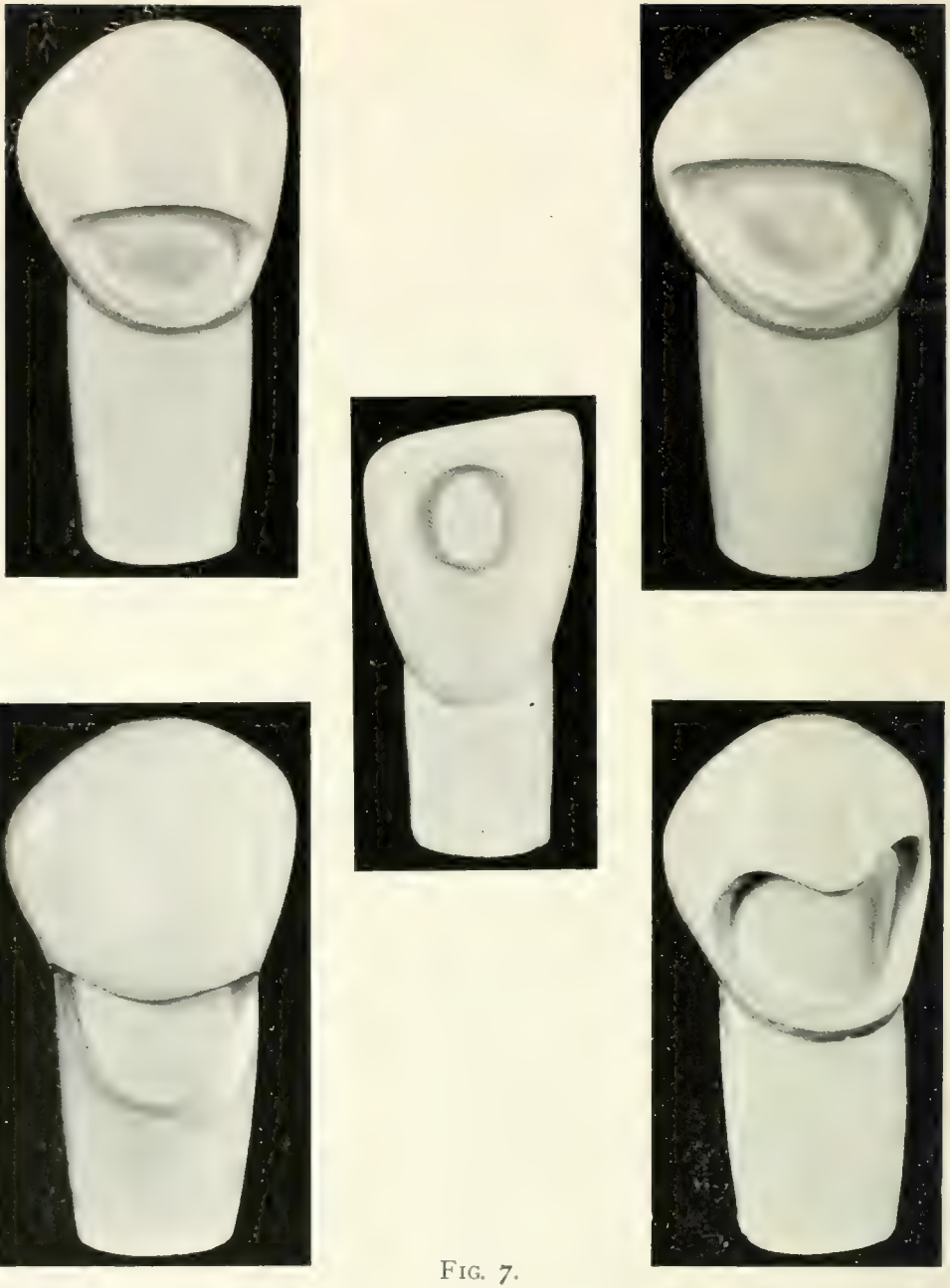


FIG. 7.

All frail enamel should be removed and the walls should run at right angles to the curves of the segments of the circles formed on the surfaces (Fig. 9, A and B). This permits the walls to converge slightly

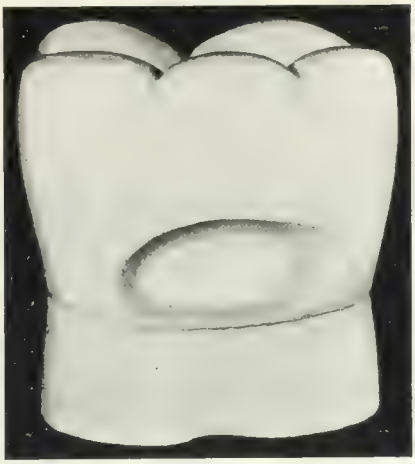


Fig. 8.

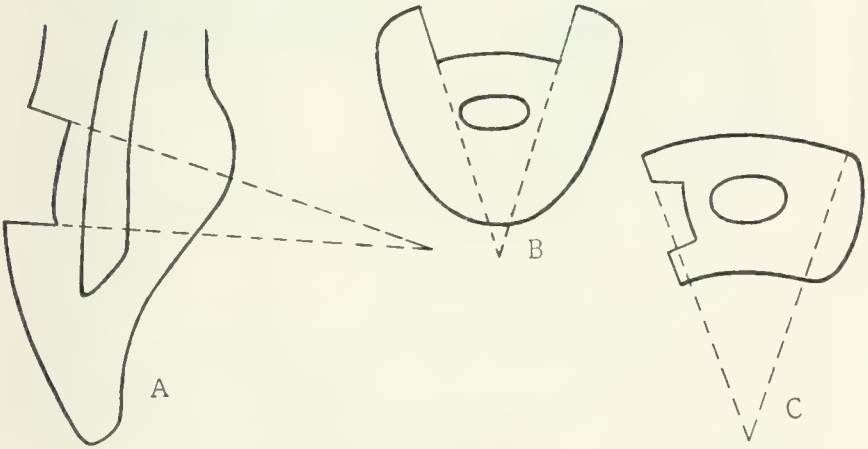


Fig. 9.

toward the pulpal wall (Figs. 10 and 11). This method of preparation gives a short bevel to the porcelain, which adds strength and causes it to be affected less by change of color along the margins after the inlay has been cemented into the cavity. These cavities should be as deep

as the pulp will permit; for as the depth of the cavity is increased, its retentive resistance is also increased, and the change in color of the porcelain, after it is cemented in place, is decreased. The pulpal wall and the plane of the surface on which the cavity is located should be parallel (Figs. 10 and 11, A). This method of preparation does not encroach upon the pulp as readily as one that requires that the pulpal wall should be flat. In case the cavity is almost circular or eliptical in outline, a pit should be drilled at some point in the pulpal wall (Fig. 12).

FIG. 10.

FIG. 11.

This insures a corresponding projection on the inlay, which assists the operator in setting it in proper relation to the cavity.

Technique of Cavity Preparation.

These cavities should be prepared by the use of fine-cut burs and stones. The best burs for the preparation of cavities on the labial and buccal surfaces are cylindrical in form (Fig. 4). The face of the bur should be at a right angle to its axis. With burs of proper size the cavity is extended in all directions to obtain proper form and size, after which the margins should be polished with Arkansas stones.

Approximal Cavities in Incisors and Cuspids.

It is essential that teeth be properly wedged before the preparation of simple approximal and approximo-incisal cavities for inlays, to insure proper withdrawal of matrices or impressions of the cavities, for the insertion of the inlay, and that the inlay may have the proper contour. The method of cavity preparation controls, in a measure, the extent of space that is required. It will be found that those cavities in which no

FIG. 12.

FIG. 13.

step is formed usually need more space than cavities with a step, for the withdrawal of matrices or impressions from such cavities.

Simple approximal cavities in incisors and cuspids may be divided into:

(1) Cavities involving the approximal and labial surfaces (Fig. 13).

(2) Cavities involving the approximal and lingual surfaces (Figs. 14 and 15).

(3) Cavities involving the approximal and both labial and lingual surfaces (Figs. 17, 18 and 19).

Cavities Involving Approximal and Labial Surfaces.

In cavities involving the approximal and labial surfaces the gingival wall should extend rootward far enough to reach sound dentine. It should form an obtuse angle with the lingual wall, and should unite with the labial enamel wall in the form of a

curve that should be concave mesio-distally. The labial enamel wall may extend farther laterally than the pulpal, and its margin should form a curve. The lingual wall should be a strong plate of enamel and should run at right angle to the pulpal wall (Fig. 13). The pulpal wall should extend from the gingival to the incisal wall in such relation that no undercuts will be formed. The incisal wall should form an obtuse angle with pulpal wall, and it should unite with the lingual wall so that the same kind of an angle will be formed. This permits the gingival and incisal walls to diverge slightly toward the labial surface.

Fig. 14.

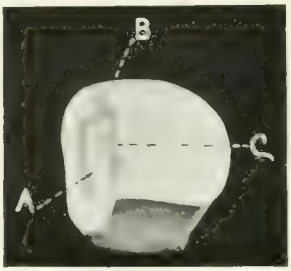


Fig. 16.

Fig. 15.

Cavities Involving Approximal and Lingual Surfaces.

In cavities involving the approximal and lingual surfaces, this method of cavity preparation should be used in those cases in which the labial wall of enamel is retained to support the incisal wall. In many cases the incisal wall of enamel can be retained with safety, where it receives the support of the labial plate of enamel. On the other hand, if the labial plate were involved it would also require the incisal angle to be involved.

The gingival wall should extend rootward far enough to insure a strong mass of porcelain on the lingual surface, and its margin should form a curve (Fig. 14). A groove may be formed, from one to three millimeters deep, which should unite with the labial and lingual walls in a curve so that no undercuts are formed with these walls, because such undercuts would interfere with the withdrawal of the matrix. The

lingual enamel wall should be in the form of a curve and should be so prepared that it will give the strongest possible support to the incisal wall. The pulpal wall should be formed in such manner that it will not interfere with the withdrawal of the matrix. The incisal wall should be a continuation of the lingual enamel wall. It should unite with the labial wall so as to form an obtuse angle.

A step may be cut on the lingual surface in the gingival and middle thirds (Fig. 15). This should extend laterally far enough to give the required retentive resistance to the inlay. The lingual enamel wall of the step should have a curved outline, and its pulpal wall should form a right angle with the pulpal wall of the cavity.

Cavities Involving both Labial and Lingual Surfaces.

In cavities involving both labial and lingual surfaces, after frail walls of enamel have been removed and the margins have been extended to the desired outline, all decay should be removed and the cavity given such form as is required for the retention of the filling.

The gingival wall should extend rootward sufficiently to carry the margin of the inlay either to or beneath the gum margin. It should be at a right angle to the pulpal wall and should have a shallow grove running labio-lingually as far as it may be extended without interfering with the withdrawal of the matrix (Fig. 16 A).

The labial wall should extend gingivo-incisally in the form of a curve. It should be prepared so that its margin runs at a right angle to the segment formed by the curve of the labial surface. (Figs. 9 C and 16 B). It would also form an obtuse angle with the pulpal wall.

The lingual wall should be cut freely to avoid any frail enamel. It should extend from the gingival to the incisal wall in the form of a curve. The plane of the curve should be parallel to that of the labial wall (Fig. 18). Enough of this wall should be removed in the gingival third to insure a strong mass of porcelain in this region.

The incisal wall should form an obtuse angle with the pulpal wall. It should extend far enough from the incisal edge to provide a strong wall of enamel.

The pulpal wall should be convex labio-lingually through the gingival and middle thirds of the tooth (Fig. 16 C). It would join the labial, lingual and gingival walls in the form of a curve instead of sharp angles.

The cavity should be triangular in shape, with the base of the triangle toward the gingival wall, being formed between the labial and

lingual walls, which should be supported by dentine. It should be as deep as the pulp will permit. The final step in the preparation of the cavity should be the preparation of the margins. The enamel walls should be properly beveled and polished. Enough of the enamel should be removed in both the gingival and incisal thirds to prevent the formation of the frail margins of porcelain.

FIG. 17.

FIG. 18.

FIG. 19.

The Technique of Cavity Formation.

After the frail enamel has been broken down with excavators or chisels, a fine-cut fissure bur of suitable diameter is used to prepare the labial and lingual margins. After the preparation of the margins the triangular cavity is cut between the enamel walls with a hoe excavator, the blade of which runs at a right angle to the axis of the shank (Fig. 6 B). The blade should be short and sharpened on both sides and the edge. This permits the cutting of the dentine along the walls of the cavity. The incisal wall of the cavity should be prepared with a small bur of such shape that it will form an obtuse angle with the pulpal wall. The margins should be polished with plug-finishing burs or Arkansas stone.

Fig. 18 shows a form of cavity preparation similar to Fig. 17, except that it extends farther toward the incisal edge. This form of preparation should only be used in those cases where the tooth is slightly rotated in such direction that no stress will be applied to the incisal angle.

Simple Approximal Cavities with a Step.

Occasionally a step may be used in simple approximal cavities. The labial outline of the cavity should have the same form as that previously described. The gingival wall, however, should extend from the labial wall through to the lingual surface, and the pulpal wall should be prepared the same as in Fig. 15.

A step should be cut on the lingual surface extending through the gingival and middle thirds of the tooth (Fig. 19). The lateral extent of this step is determined by the degree of stress to which the tooth is subject. It should be as deep as the pulp will permit. The pulpal wall of the step should form a right angle with the pulpal wall of the cavity. Care should be exercised to prevent the step from extending too near the incisal edge.

Technique of Preparing the Step.

The enamel should be removed laterally from the gingival to the incisal wall with a dentate fissure bur and small stones in the right angle. After this has been done, a fissure bur with face at a right angle with its axis should be used to deepen the cavity. Enough of the gingival should be involved to prevent frail margins of porcelain in this region. The margins should be finished with properly shaped plug-finishing burs or Arkansas stones. A slight groove should extend along the angle of the pulpal and lateral wall of the step in the gingivo-incisal direction (Fig. 19 A). The cavity should be so prepared that the distance from the gingival to the incisal margin on the lingual surface is greater than this distance on the labial surface (Fig. 19 B).

Chapter III.

Preparation of Cavities.

Approximo-Incisal Cavities; Formation Without Step; Formation With Step. Mesio-disto-incisal Cavities. Cavities Involving Incisal Edge. Teeth Affected by Malformation and Erosion. Cavities in Bicuspids and Molars.

Approximo-Incisal Cavities.

Approximo-incisal cavities may be divided into two classes: Approximo-incisal cavities involving but a small portion of the incisal angle and where no step is required for retentive resistance; and approximo-incisal cavities involving enough of the incisal angle to require a step for additional retentive resistance.

Preparation of Cavities Without a Step.

The gingival margins should be slightly concave in a labio-lingual direction (Fig. 20 A). This gives the shortest possible bevel to the porcelain in the linguo-gingival region, thereby insuring less liability to fracture. The labial margin should be cut laterally far enough in the gingival region to avoid a frail margin of porcelain; it should unite with the gingival margin in the form of a curve and extend incisally in the form of a straight line (Fig. 21 A). The labial margin should run at right angles to the curve of the segment of the circle formed on the surface (Figs. 9 C and 17 B). The lingual margin should extend from the gingival wall to the incisal edge in a straight line, and it should be cut as far laterally as the labial margin. This margin by being sufficiently extended in a gingival direction, should involve enough of the gingival ridge to provide for a thick mass of porcelain in this location (Fig. 21 B).

Formation of the Cavity.

The gingival wall should be slightly grooved and should form a right angle with the pulpal wall: it should extend far enough rootward to protect the gingival margin. A shallow groove should be cut from the labial to the lingual wall, but care is to be taken that this groove

should not interfere with the withdrawal of the matrix (Fig. 16 A). A triangular cavity should then be cut between the labial and lingual walls, extending from the gingival to the incisal wall (Fig. 20 B). The labial and lingual walls should slightly diverge toward the margins, and the incisal wall should form a slightly obtuse angle with the pulpal wall, which should be convex so that the pulp in deep cavities may be protected. The cavity should be as deep as the pulp of the tooth will permit.

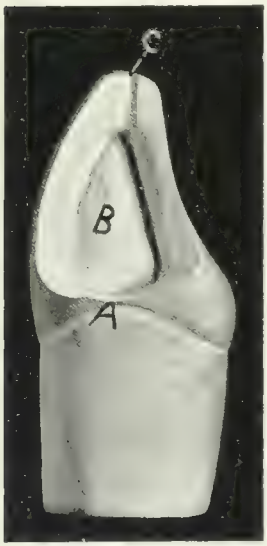


FIG. 20.

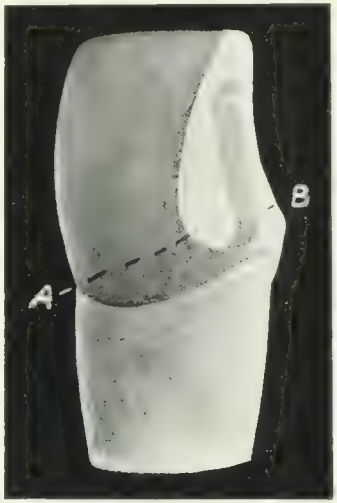


FIG. 21.

Technique of Cavity Formation.

The enamel should be removed with chisels and knife-edge stones. After the enamel margins have been properly formed, the triangular cavity should be cut in the dentine between the labial and lingual walls (Fig. 20 B), with the special hoe excavator (Fig. 6 B). In order to break the straight line of cement a shallow groove should be formed, with a fissure bur, extending from the incisal wall of the cavity to the incisal edge, between the labial and lingual enamel plates (Fig. 20 C). After the cavity has been prepared the margins of the cavity should be properly finished with sharp chisels, finishing burs, and Arkansas stones.

After the inlay has been constructed, a very shallow groove should

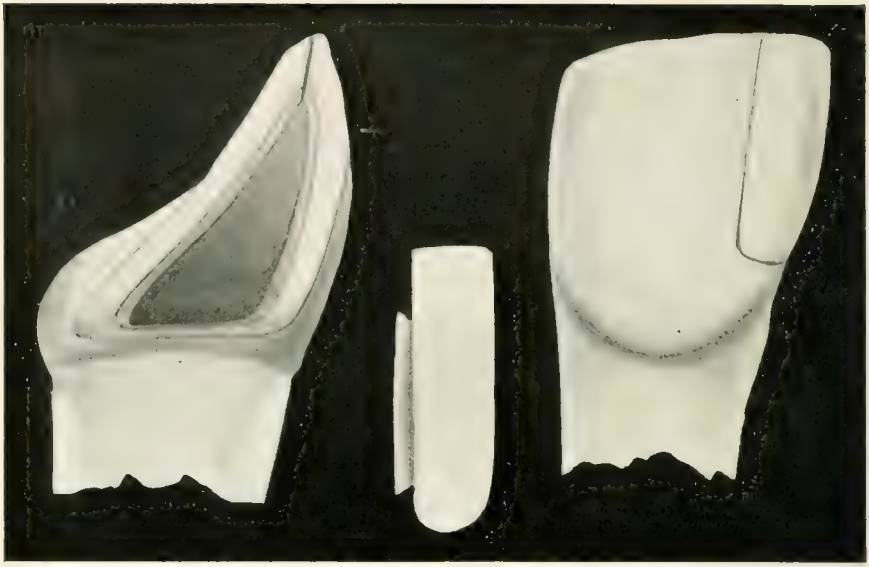


Fig. 22.

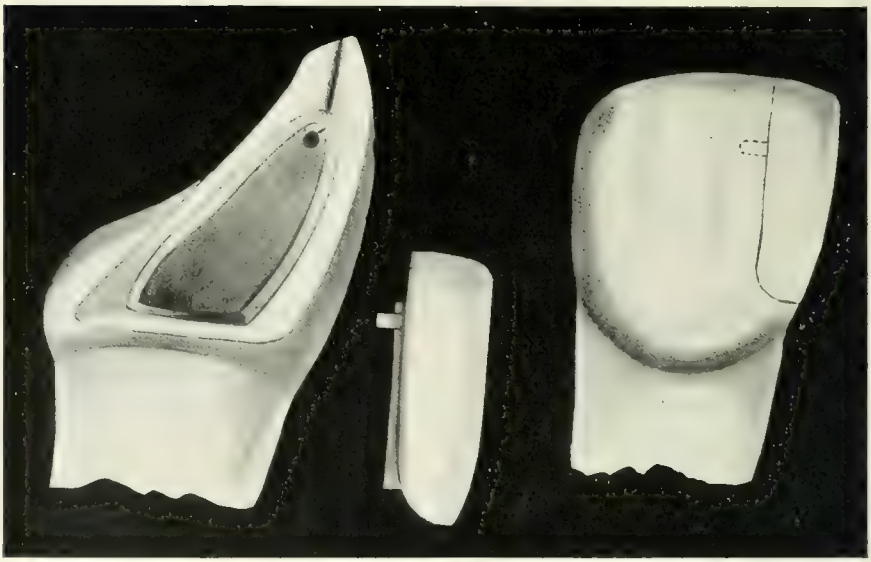


Fig. 23.

be made along the labial and lingual walls at their union with the pulpal wall, and a slight concavity should be made in the dentine of the incisal wall. Grooves should be formed along the walls of the ridge of the inlay which fits in the cavity. When the inlay is cemented into position, this gives it something of a mortised form of retention (Fig. 22).

In case only a shallow cavity can be cut between the labial and lingual walls, and more retentive resistance than this would yield is

FIG. 24 A.

FIG. 24 B.

FIG. 24 C.

required, a hole, two mm. deep, running at right angles to the axis of the tooth, may be drilled between the enamel plates and as far from the incisal edge as the pulp will permit (Fig. 23). A threaded pin from three to four mm. long No. 19 gauge platinum wire is then inserted through and attached to the matrix. The pin becomes an integral part of the inlay, and may give the necessary retentive resistance in many cases. This method can not be used, however, unless sufficient space can be secured for the insertion of the inlay. It is also contraindicated in those teeth, whose enamel plates are thin; for the resistance from the enamel plates or the porcelain would not be sufficient to retain the inlay, and the reflection from the platinum pin would affect the color of the enamel and the porcelain. The author believes that this method of cavity preparation is a poor one and questions the advisability of its use.

Approximo-Incisal Cavities With Steps.

Marginal Outline.

The labial margin may extend from the gingival wall to the incisal edge in the form of a straight line (Fig. 24 A), or it may extend from the gingival margin to the incisal third in the form of a straight line, then extend laterally in the form of a curve (Fig. 24 B and C).

Fig. 25.

Fig. 26.

Fig. 27.

Preparation of the Cavities.

Since the necessity for retentive resistance increases in proportion to the increased width of the inlay, a step should be made in large approximo-incisal cavities to resist the tipping stress. The method of cavity formation is, in a measure, dependent upon the method of step formation. Steps may be formed by involving additional area of the lingual surface. They may involve only the incisal third, they may extend from the incisal edge to the gingival wall, or they may involve the middle and gingival thirds. They may also be formed by involving both labial and lingual plates in the incisal third.

Step in Lingual Surface Only.

A step may be formed involving only the lingual plate in the incisal third of those teeth with thick incisal edges (Fig. 25). It should involve at least one-half the thickness of the incisal edge and extend from three to four millimeters gingivally. The gin-

gival wall of the step should form a right angle with the cancavity of the lingual surface. A slight groove may extend along the approximo-labial angle of the step in order to give additional retentive resistance. This method of step preparation is considered unsafe for general usage. It should never be used where great stress may be applied to the porcelain. The weak point of the inlay is at the union of the porcelain for the cavity

FIG. 28 A.

FIG. 28 B.

and the step, and an undue amount of stress will cause it to fracture at this point.

In those cases in which the step extends from the incisal edge to the gingival wall this wall should be flat. The labial margin should unite with the gingival in the form of a curve and extend to the incisal edge in the form of a straight line. It should form a right angle with the mesio-distal curve of the labial surface. Enough of the labial wall should be involved to insure sound enamel supported by dentine, and it should be so prepared that it will form an obtuse angle with the pulpal wall. The lingual wall should extend laterally about two millimeters further than the labial and should run parallel with it. The pulpal wall should be convex and form an acute angle with the pulpal wall of the step.

Technique of Step and Cavity Preparation.

After the frail walls of enamel have been removed with a chisel, a knife-edged carborundum should be used to remove the remaining enamel of the labial wall. A small narrow stone should then be used to grind the enamel on the lingual surface from the gingival wall to incisal edges. After the enamel has been partially

FIG. 28 C.

FIG. 29.

removed from the lingual surface, flat faced fissure and diamond burs in the right angle should be used to cut the enamel so that it will have proper marginal form and to remove enough of the dentine to give the step proper depth (Fig. 26). With a fissure bur in the straight handpiece the labial and pulpal walls should be so prepared that they will unite in the form of an obtuse angle. A shallow groove should run along the gingival wall. Another groove should be made at the union of the axial and pulpal walls of the step from the gingival wall to the incisal edge (Fig. 26 A).

Or a step may be prepared involving the middle and gingival thirds (Fig. 27). It should extend laterally far enough to give sufficient retentive resistance. The gingival and incisal walls which should unite with the axial wall in curves should converge slightly toward the axial wall of the step. The pulpal wall of the step should be flat and should be so pre-

pared that it will not interfere with the withdrawal of the matrix. The step should be as deep as the pulp will permit.

Step in Labial and Lingual Surfaces.

In all cases in which the enamel plates are thin in the incisal third, or in which there has been an extensive loss of the incisal angle, the step should involve both labial and lingual plates of the incisal edge (Fig. 28, A and B). This insures a stronger

FIG. 30.

FIG. 31.

FIG. 32.

mass of porcelain and greater protection to the enamel. It also prevents the cement from changing the color of the tooth by reflecting through the thin plate of enamel.

One of the weakest points of a porcelain inlay is the incisal margin. if the enamel is beveled so that it is protected by porcelain, the thin margin of porcelain which will be formed may be subjected to enough stress to cause it to fracture. If the enamel is not beveled so that it is protected, the enamel itself may fracture. In all cases in which it can be done, the author tries to form the axial margin of the step near the center of the tooth, thereby leaving the enamel rods running almost parallel with the axis of the crown.

A step involving the labial plate should be so prepared that enough tooth structure is involved to give a mass of porcelain sufficiently strong to withstand the force of mastication, and to resist both vertical and

lingual stress. The step should be cut across the incisal edge, extending from one and one-half to three millimeters; it should be from one and one-half to two millimeters deep on the labial surface (Fig. 28 C).

Fig. 29 shows a form of cavity preparation similar to Fig. 26, except that the step involves both labial and lingual plates. The labial plate should form a reverse curve with the axial margin of the cavity. Its margin should be so prepared that it will form a right angle with the inciso-gingival curve of the surface. The gingival and middle thirds of the step should be prepared similar to the preparation of the step for Fig. 26. The lingual plate of the axial wall of the step should be cut further laterally than the labial, or a shallow groove should be made between the two plates with a fissure bar. This breaks the straight surface formed in a labio-lingual direction, and thus assists in preventing the cement from washing from the joint for the entire width.

Figs. 30, 31 and 32 show methods of step preparation, which, in the author's opinion, give the best results in most cases in which there has been extensive loss of tooth structure. The labial and lingual margins of the step should form right angles with the gingivo-incisal curves of these surfaces. They should form reverse curves with the axial margins of the cavity. In those teeth with thick incisal edges, a shallow cavity may be cut between the labial and lingual plates when these plates are approximately the same length (Fig. 30). In teeth with their incisal edges, the lingual plate should be cut almost half the thickness of the incisal end, and should extend farther gingivally than the labial plate (Figs. 31 and 32). It should be so formed that its gingival wall will be at right angles to the concavity of the lingual surface. The axial-lingual plate of enamel of the step should be cut further laterally than the labial, or a shallow groove should be cut between the labial and lingual plates of the step.

The preparation of the cavities for Figs. 25, 30, 31 and 32 is as follows: The gingival wall should be concave labio-lingually, and it should run at right angles to the pulpal wall, and its margin should unite with the margins of the labial and lingual surfaces in such manner that it will be concave mesio-distally. Both the labial and lingual walls should be parallel. They should slightly converge toward the center of the tooth as they approach the incisal edge, and their margins should run at right angles with the curve of the surface. A triangular cavity should be cut between these walls, gradually diminishing in depth toward the incisal edge (Fig. 30). The labial and lingual walls of the cavity should unite with the pulpal walls in such a manner as to form slightly obtuse angles.

Lower incisors receive stress in a vertical and labial direction. In the preparation of step cavities in these teeth, where the step involves only

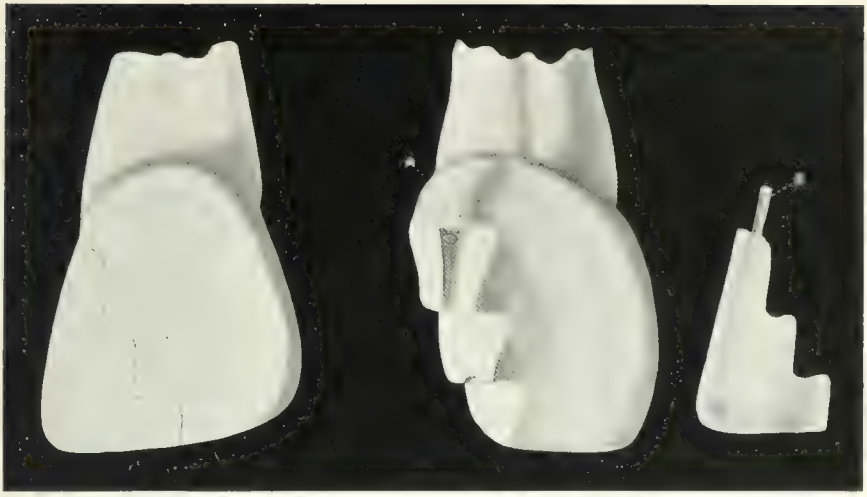


FIG. 32.

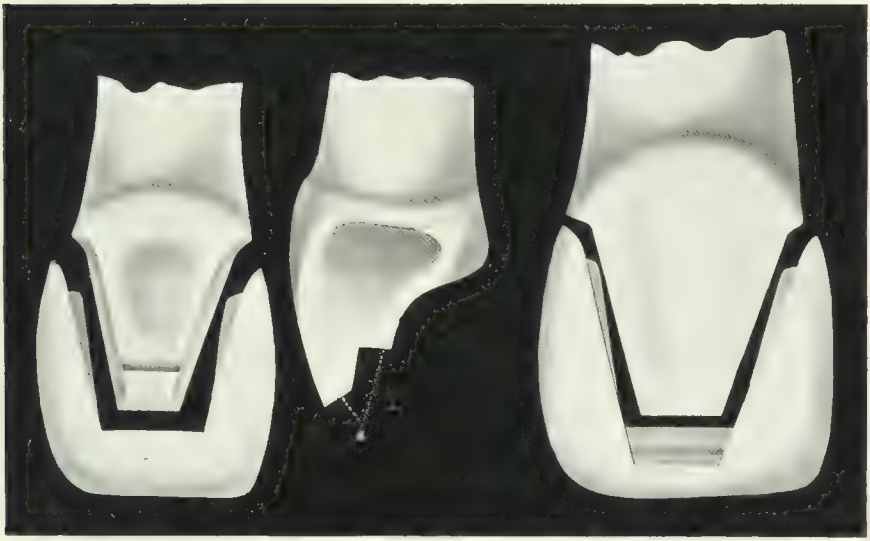


FIG. 33.

the labial plate, it should be cut on the labial surface in the incisal third. This preparation is the reverse of that shown in Fig. 25. In case both labial and lingual plates are involved the preparation that is shown in Fig. 30 with such modifications as are necessary to resist the labial stress is indicated.

A method of preparing approximo-incisal cavities by cutting a series of reverse curves, as illustrated in Fig. 32, may be used for the preparation of some cavities to prevent frail enamel walls. The advocates of this method claim that this iregular outline results in a less conspicuous line of demarcation between the porcelain and the enamel, and that the series of reverse curves gives the essential acute angle resistance for the porcelain of the inlay. It has been found advisable to drill a hole rootward (Fig. 32 A), which should be about No. 18 gauge. This hole should run parallel with the axis of the tooth and should be from three to five millimeters deep. It should be drilled after the matrix has been properly formed. Then a piece of threaded platinum wire, No. 19 gauge, should be inserted into the hole and permitted to extend about two millimeters beyond the matrix. When the inlay is constructed, the post is attached in the porcelain and offers additional retentive resistance after the inlay has been set (Fig. 32 B).

Mesio-Disto-Incisal Cavities.

The question may arise with some as to the advisability of inserting these large compound inlays instead of crowning the teeth. It must always remain a matter of personal equation just when to substitute crowns for fillings, but the author believes that a tooth with a vital pulp, presenting sufficient structure to retain a filling for a reasonable period, should be filled. Many times these fillings will last for years and when the filling is lost the tooth presents the same opportunities for crowning that it did before it was filled.

The labial and lingual walls of both cavities should converge toward the incisal edge and their margins should form right angles with the curves of the surfaces (Figs. 33 and 34). Both labial and lingual plates should be involved in the incisal third and the lingual plate should extend farther gingivally than the labial (Fig. 34 and Fig. 35). The gingival walls of both cavities should extend to the gum margin and should run at right angles with their pulpal walls. If the pulp will permit, shallow triangular cavities should be cut between the labial and lingual walls in the gingival third, gradually diminishing in depth through the middle third.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

The labial and lingual walls of the cavities should slightly diverge from the pulpal wall. This form of cavity preparation is particularly indicated in the preparation of mesio-distal cavities in lower incisors. The step should be changed so that the labial plate of the incisal edge is involved instead of the lingual, thereby making the resistance from the lingual surface.

Fig. 38.

Fig. 39.

Fractures of Incisors.

One of the most perplexing forms of cavities is found in those cases where only a small portion of the approximo-incisal angle has been lost by fracture (Fig. 36). Such fractures can be successfuly treated by forming the cavity on the lingual surface without further involving the labial plate. Fig. 36 shows the labial outline, while Fig. 37 shows the cavity formed in the lingual surface. Enough of the lingual surface should be included to form a step of sufficient area to retain the inlay securely. The labial wall of the step should be flat, while the gingival wall should form a concave surface. The axial wall of the step should run almost parallel with the long axis of the tooth, and it should form an acute angle with the labial wall.

In case of more extensive diagonal fractures of the incisal edge and where the pulp remains vital (Fig. 38), it has been found advisable to

protect the pulp by the remaining dentin and to retain the inlay by preparing the cavity with a series of reverse curves (Figs. 39, 40 and 41). Fig. 39 shows the cavity formation for the labial surface and Fig. 40 shows the formation of the lingual. The gingival wall should form a concave surface, mesio-distally (Fig. 39A.) Reverse curves should be cut in the labial and lingual plates about midway between the gingival wall and the

FIG. 40.

FIG. 41.

incisal edge (Figs. 39 B, 40 B and 41 A). A third reverse curve, involving both labial and lingual plates, should be formed at the incisal edge (Fig. 39 C). A shallow groove should be cut between the enamel plates in the incisal region to break the plane surface, formed by the enamel plates, in this region (Fig. 41 B).

In case the pulp is involved, the inlay may be retained by a post inserted into the canal. The margins should be smoothed, after which the pulp-chamber should be so prepared that the matrix may be withdrawn. After the matrix has been constructed, a 16 gauge irridio-platinum post should be inserted through the matrix into the pulp canal. The post should extend far enough through the matrix to give sufficient retention to the porcelain and that end around which the porcelain is fused should be roughened to give it secure attachment.

Cavities Involving the Incisal Edge.

Simple cavities in the incisal edges of the anterior teeth are usually caused by malformation. The mesial and distal walls of the cavities should extend gingivally from two to four millimeters, and should slightly diverge toward the incisal edge (Fig. 42). They may be slightly

FIG. 43.

FIG. 42.

FIG. 45.

FIG. 44.

grooved between their plates of enamel to resist the lingual stress (Fig. 43). The seat should be flat and should be grooved between the labial and lingual walls.

Another form of cavity preparation for this class of cavities is as follows: Prepare the labial outline as in Fig. 42. The lingual wall should be cut farther in every direction, forming a step (Fig. 44). Two shallow

grooves may be made between the plates of enamel, extending from the seat of the cavity toward the incisal edge in such a manner that they slightly diverge.

Cavities involving the entire incisal edge are very rare (Fig. 45). The inlay must be retained by pins and by a step. Figs. 46 and 47 show a form

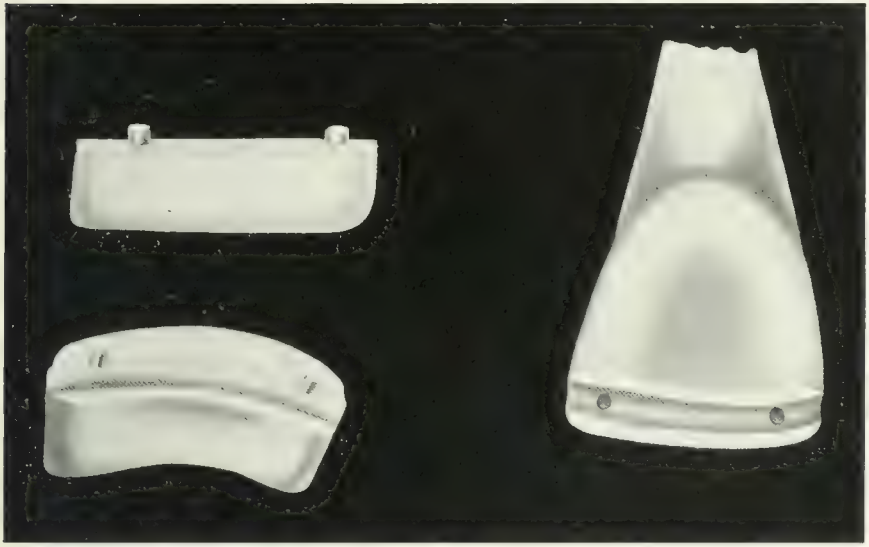


Fig. 46.

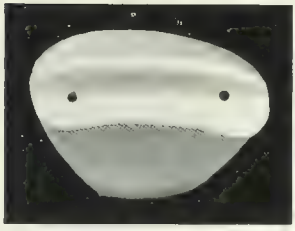


Fig. 47.

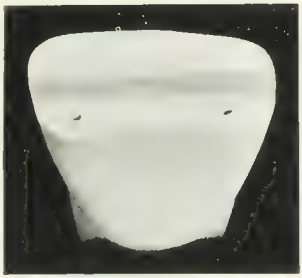


Fig. 48.

of preparation for retaining the inlay by pins. The tooth should be ground until sound structure well suported by dentin is reached, then a V-shaped groove should be cut in a mesio-distal direction across the tooth. The edges of this groove should be so formed that the cavity bevels toward the center, the bevel being at about right angles to the curve

of the surface. After the matrix has been constructed, two holes extending parallel and in a rootward direction, should be drilled with a round bur, No. 18 gauge. Platinum pins, No. 19 gauge, should be inserted in these holes with a matrix in position, and porcelain mixed to a thick consistency should be packed around the heads of the pins and

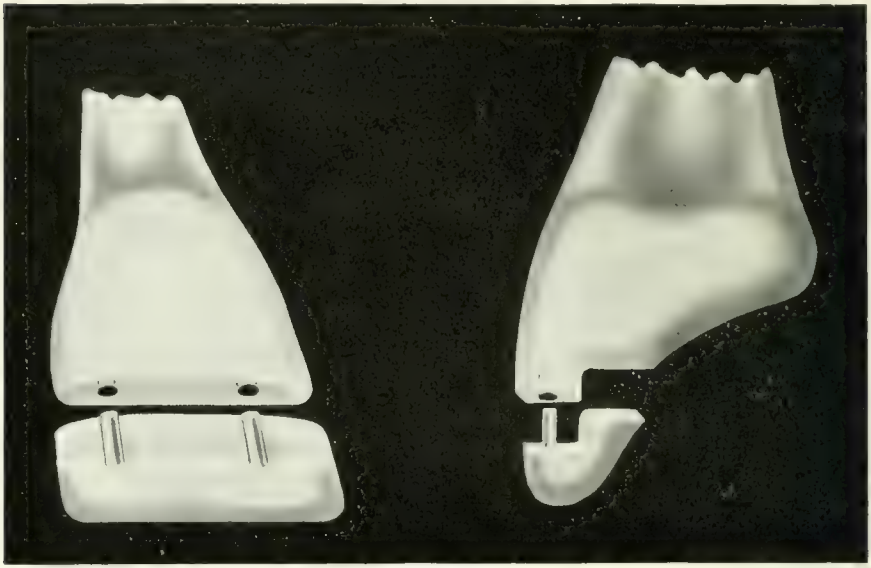


Fig. 49. Fig. 50.

fused to a high biscuit. The matrix should be again adjusted and reburnished.

Figs. 48, 49 and 50 show a form of cavity preparation where a step is cut on the lingual surface. The lingual margins should extend at least two millimeters farther gingivally than the labial and should be cut about one-half the thickness of the incisal end, provided the pulp will permit. Pins may be used with this method of cavity preparation to give additional retentive resistance.

The Treatment of Teeth Affected by Malformation and Erosion.

In many cases of malformations, the teeth are usually marked by pits and grooves; they present an atrophied condition, and their incisal halves are partially denuded of enamel. If more than the incisal one-half is involved, the malformation can be corrected best by con-

structing an all porcelain jacket crown. If, on the other hand, less than the incisal one-half is involved, the condition may be remedied with less pain and annoyance to the patient by the use of a jacket partial crown. Such an operation is not indicated unless the tooth can be prepared in such manner that the remaining stump affords a secure attachment and permits a sufficient bulk of porcelain to insure strength.

FIG. 51.

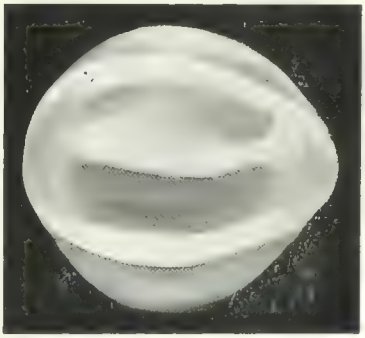


FIG. 52.

The approximal walls should converge slightly toward the incisal edge (Fig. 51), and the shoulders formed by their termination should run at right angles to the axis of the tooth. The shoulders formed on the labial and lingual surfaces should run at right angles to the curves of these surfaces. Enough of these walls should be involved to give a sufficient bulk of porcelain and to prevent the tip from appearing bulky and unsightly (Fig. 52).

The approximal walls should be prepared with knife-edge stones, while the remaining enamel should be removed from the labial and lingual surfaces with flat-face diamond and fissure burs (Fig. 4A and 5B). After which plug finishing burs and Arkansas stones (Fig. 4B and 5C) should be used to polish the tooth stump.

In case of extensive erosion on the labial surface and where there is no decay on the approximal or lingual surfaces, the tooth may be

FIG. 53.

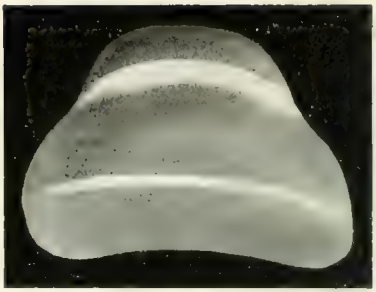


FIG. 54.

FIG. 56.

FIG. 55.

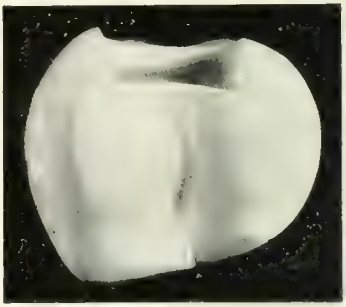


FIG. 57.

treated by constructing a veneer of porcelain for the labial surface. It has been found that such operations check erosion and preserve the vitality of the tooth for an indefinite period. A shoulder following the curvature of the gingival line (Fig. 53) should be formed across the labial surface, and enough of this surface should be involved to permit the porcelain to be of a sufficient thickness to insure strength and to prevent a change of color by the cement (Fig. 54). The entire incisal edge should be involved to insure proper retentive resistance and to prevent fracture of the porcelain. The incisal wall should form an acute angle with the labial surface (Fig. 55).

After the incisal edge has been removed with flat-face stones, sufficient enamel and dentin should be removed with stones from the labial surface to insure proper thickness of porcelain. Then the shoulder should be formed with flat-faced fissure burs at the gum margin. After this has been done the approximal margins are to be made smooth with sharp chisels and Arkansas stones.

The Preparation of Cavities in Bicuspids and Molars.

Experience has proved that porcelain is not the best filling material for most cavities in bicuspids and molars. Their occlusal surfaces present a series of inclined planes which when restored with a friable material, lacking in edge strength, may cause imperfect fillings in a short time, by the breaking of the margins of these fillings. There are, however, many cavities in these teeth that should be filled with porcelain for the cosmetic effect. The marks of occlusion should be studied in the preparation of occlusal and approximo-occlusal cavities, and their margins should be carried to points where they will have the least masticatory stress, for thereby the life of the filling is increased. If cavity margins are formed at points at which the stress is unduly strong, these margins of porcelain will fracture and leave faulty fillings.

The function of a filling is: first, to check the existing decay and to prevent if possible its recurrence; second, to restore the original form of the tooth in order that it shall maintain its proper relation with the other teeth and to protect the gum in the inter-proximal space, and third, to meet the cosmetic requirements. While porcelain is not indicated in many forms of cavities in bicuspids and molars, there are cases in which we should not lose sight of the cosmetics, and in such cases porcelain should be given due consideration. Gold foil and amalgam have preserved many teeth for a considerable length of time, but when we note the number of failures that have been made with

these materials, we feel that we are justified in considering the inlay principle of filling cavities in bicuspids and molars.

It is essential that teeth with approximo-occlusal cavities be wedged, in order that the gum in the inter-proximal space may be protected; that the margins of the filling may be more easily cleansed; that the tooth when filled may be given its natural contour and that

Fig. 58.

Fig. 59.

the matrix or impression may not be distorted upon removal from the cavity. Too many dentists lose sight of the advantages of wedging the bicuspids and molars before filling cavities in these teeth. It is just as important to wedge these teeth before filling as it is to wedge incisors and cuspids. If more attention were paid to this step of the operation, there would be fewer cases of recurrence of decay at the margins of fillings.

Approximo-Occlusal Cavities.

In case the patient has reached the period of immunity, and there are no fissures extending from the cavity, mesio-occlusal cavities in bicuspids and first molars, without a step may be filled with porcelain. The axial margins should be extended far enough so that they will not come in contact with the approximating tooth.

The gingival wall should be flat and should form a right angle with the pulpal wall. The buccal and lingual walls should diverge toward the approximal and occlusal margins (Fig. 56). The walls should be grooved in the dentin occluso-gingivally to form mortices (Fig. 57), and they should run at right angles with the approximal surface.

Approximo-Occlusal Cavities with a Step.

The gingival wall should be flat and should form a right angle with the pulpal wall. The buccal and lingual walls should be so prepared that their margins extend in straight lines which slightly diverge toward the occlusal surface (Fig. 58). These walls

Fig. 60.

should converge slightly toward the pulpal wall and they should unite with this wall in the form of a curve.

The step should be deep enough to insure strength to the porcelain, and if possible it should be wide enough to form its margins at points where there is no masticatory stress. Its seat should be flat and at right angles with the pulpal wall. Its axial walls should diverge toward the approximal marginal ridge (Fig. 58A), and also toward the occlusal surface.

Large Approximo-Occlusal Cavities.

In extensive cases the buccal and lingual cusps should be involved and the cavity margins extended on the buccal surfaces, obliterating to a large degree frail margins of porcelain on the occlusal surface. The gingival wall should be flat and at right

angles with the pulpal wall, and its margins should unite with the buccal and lingual margins on these surfaces (Fig. 59). The buccal and lingual margins should extend occlusally in the form of a straight line to the occlusal third and then they should extend laterally in the form of a reverse curve to the axial walls of the cavity, uniting with the occluso-axial margins of the cavity in the form of a curve (Fig. 60).

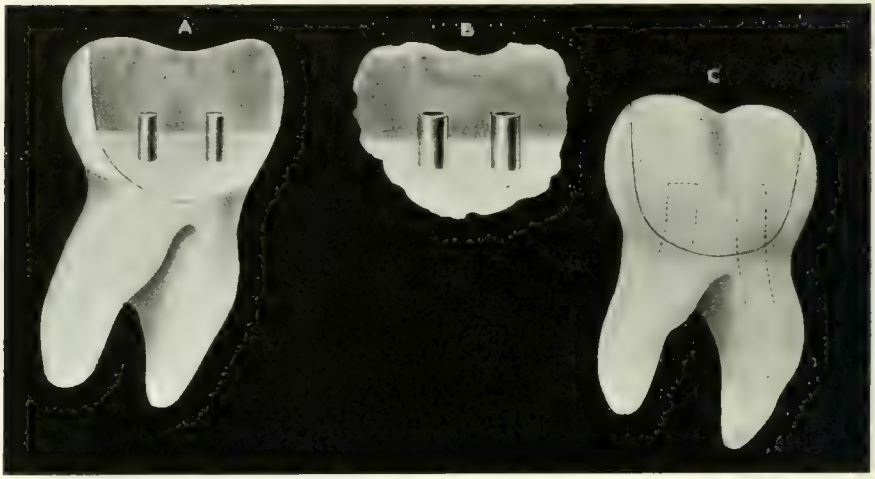


Fig. 61.

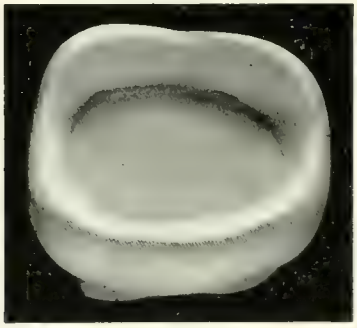


Fig. 62.

The walls of the cavity should slightly diverge from the pulpal wall in both directions.

In cases of bucco-occlusal or approximo-occlusal cavities involving most of the crown of the tooth and extending beyond the gingival line the cavity may be prepared as outlined in Fig. 61A. The posts

are inserted in one or more canals and platinum caps are made to fit over them. The matrix is burnished to conform to the walls of the cavity and the caps are held in relation by sticky wax. After chilling the wax, the matrix and caps are removed, and soldered (Fig. 61B). The porcelain is then fused around the caps and the matrix is readjusted for the final burnishing. The matrix becomes a part of the inlay and should be properly trimmed to conform to the margins of the cavity after the inlay has been finished. After the inlay has been set the matrix should be finished to the margins of the cavity as a subsequent operation (Fig. 61C).

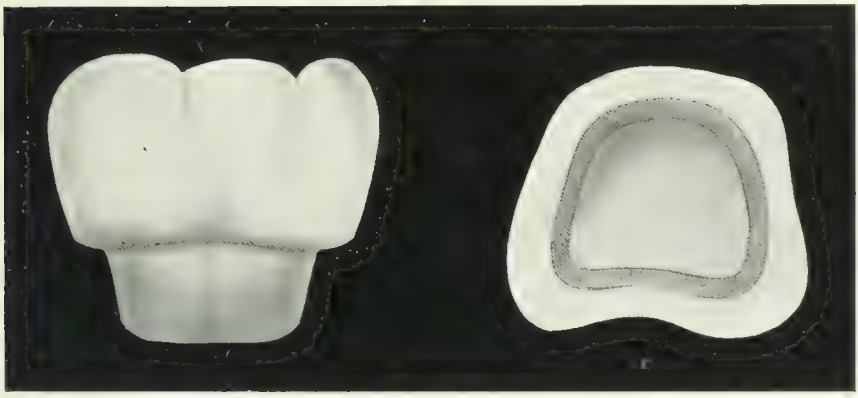


Fig. 63.

Deep Cavities in the Occlusal Surface of Molars.

Cavities in lower molars involving the occlusal surface to the marginal ridges leaving the axial walls unsupported by dentin and in which there is no decay on the approximal surfaces, may be filled with porcelain. The margins of the cavity should involve the marginal ridges and they should be beveled in such a manner that they form obtuse angles with the axial walls of the cavity. The pulpal wall should be flat. The axial walls should be extended far enough to protect the margins from stress and they should form slightly obtuse angles with the pulpal wall. (Fig. 62.)

For pulpless molars where the entire occlusal surface is involved, the pulp chamber is so prepared that the axial walls are slightly di-

vergent (Fig. 63). The occlusal margins are beveled to form slight obtuse angles with the axial walls. In case additional retentive resistance is required, a post may be inserted in one canal and permitted to extend far enough into the porcelain to give a strong retention. While this gives an entire crown of porcelain, the principle of construction is the same as applied to that of inlays.

Chapter IV.

The Formation of Matrices for Porcelain Inlays.

Matrix Metals. Methods of Constructing. Technique of Burnishing. Impression Methods. Models of Cavities; Amalgam; Cement. Devices and Methods of Swaging. Refitting Matrices.

Before describing the methods of forming matrices, let us consider the materials that are used for this purpose. Such a consideration shows that gold, platinum and platinous gold are used for the construction of matrices, and that each material has properties characteristic of it. In formulating a table for comparison of these three metals, the numbers used for such comparison refer to this particular table and not to the general table used in the comparison of metals.

Gold. Fusing point 2016° F. Malleability, first rank; tenacity, third rank; pliability, first rank; ease of annealing, first rank.

Platinum. Fusing point above 3500° F. Malleability, third rank; tenacity, first rank; pliability, third rank, and ease of annealing, third rank.

Platinous Gold. (One to three per cent): Fusing point, approximately from 2030° to 2040 F. Malleability, second rank; tenacity, second rank; pliability, second rank; and ease of annealing, equal to that of gold.

Gold and platinous gold can only be used to advantage with low fusing, while platinum can be used with high or low fusing porcelains. Matrices can be constructed of platinous gold as thin as 3/10000 of an inch, while pure gold thinner than 4/10000 of an inch can not be manipulated to good advantage. They may be constructed of platinum foil as thin as 1/2000 of an inch, but the best results are generally obtained by the use of foil 1/1000 of an inch in thickness.

There are cases in which pure gold as thin as 4/10000 of an inch may be used for the construction of a matrix, for small cavities of free accessibility, but of this thickness, gold is so pliable that the danger of

distortion precludes its use in cavities where the matrix can not be easily removed. Since the pliability of metals decreases, and their tenacity increases in direct ratio to their thickness, the gauge of the metal used should be determined largely by the conditions presented by the cavity in hand.

Of the metals used for matrices, the author believes platinum to be the best for the construction of matrices of large cavities. While gold and platinous gold are more pliable than platinum and are apparently more easily manipulated, the tendency of a matrix made of them to distortion, either in the process of withdrawal or during the process of

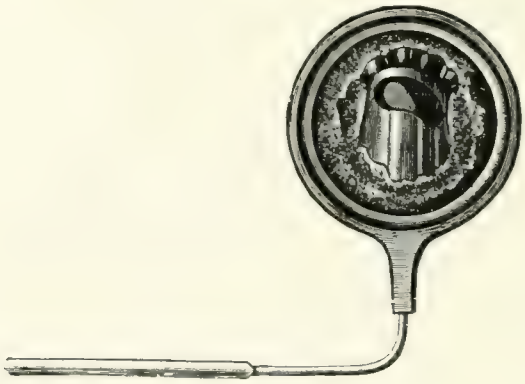


FIG. 64.

fusing the porcelain, seems to be somewhat of a disadvantage. Some operators invest matrices, made of thin foil, to prevent the porcelain from changing their shape (Fig. 64), but the time consumed in investing the matrix and in cooling it after each baking will be greater in total than the additional time consumed for the construction of a platinum matrix. Platinous gold has more elasticity than pure gold, but is more liable to tear during the process of swaging or burnishing.

Annealing Matrix Metals.

Gold and platinous gold are annealed by the heat of a gas or alcohol flame. But extreme care must be exercised to prevent these metals from partially fusing during this process. The metals should be passed through the flame several times and should never be held in an intensely hot flame for any considerable length of time, because of the comparatively low temperature at which they fuse. Platinum should be annealed in the furnace or in an oxyhydrogen flame. The method of

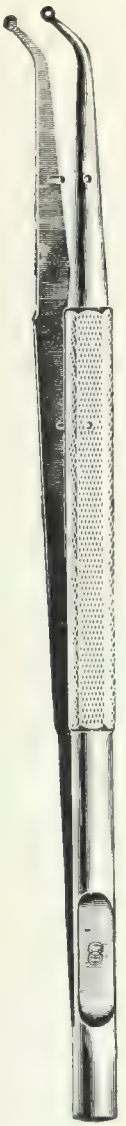


FIG. 65.

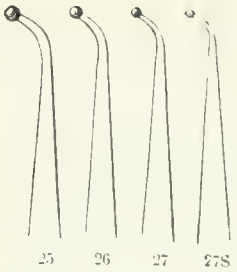


FIG. 66.

FIG. 67.

FIG. 68.

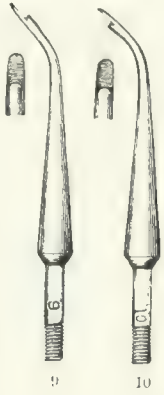


FIG. 69.

annealing it in a gas or alcohol flame is to be condemned; for the comparatively low heat obtained from these flames seems to render the metal slightly brittle. It should be heated in the furnace to about 2200° F. for two or three minutes, by which process it becomes more pliable.

There is no particular advantage in annealing the matrix several times during the process of construction. The foil should be made pliable previous to beginning the formation of the matrix, and there is no need of further annealing unless the foil loses its pliability during the construction of the matrix.

Methods of Constructing Matrices.

There are three general methods of constructing matrices for cavities.

(1) Burnishing directly into the cavity.

(2) Swaging into a model of the cavity.

(3) Swaging over an impression of the cavity.

The method of burnishing the foil directly into the cavity seems to be the most popular, and the author believes it to be the best for the construction of matrices for simple approximal and most approximo-incisal cavities. If the foil is burnished directly into the cavity, it gives a sharper matrix than can be made by swaging directly into the models of many cavities. Matrices can be removed from simple approximal cavities where there is a moderate amount of space, with no danger of distortion, while an impression of the cavity could not be removed without additional space or sacrifice of tooth structure. A matrix burnished into a cavity usually covers more of the surface of the tooth than one swaged into a model, thereby aiding the operator when applying the porcelain, to obtain better representation of tooth contour.

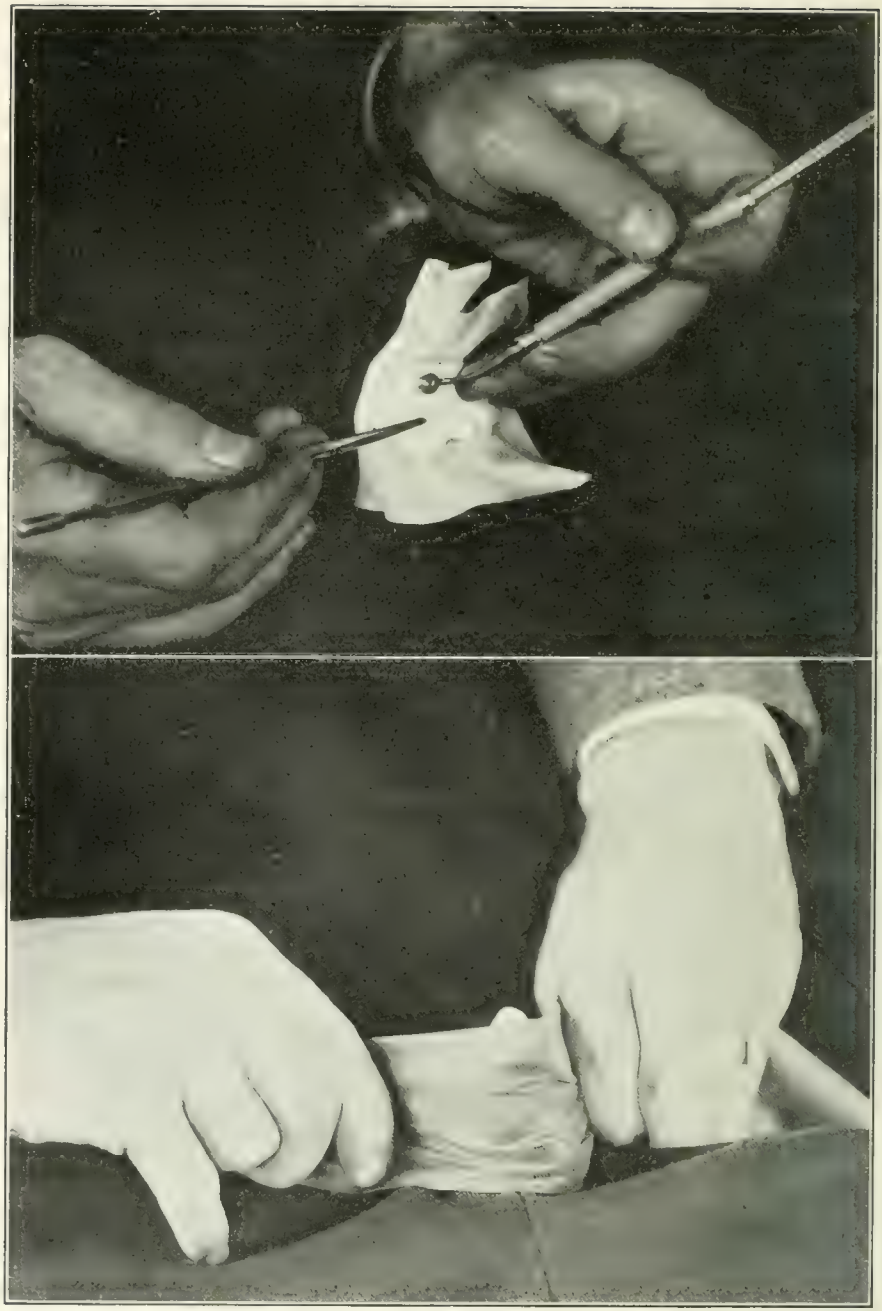
There have been a number of special instruments for burnishing matrices placed on the market. It has been the author's experience, however, that many of them are useless and that a large supply of burnishers is more of a hindrance than a help in this work. He has found that a pair of special inlay matrix pliers (Fig. 65), four ball burnishers (Fig. 66), one blade burnisher (Fig. 67), one special marginal burnisher (Fig. 68), and two gingival marginal burnishers (Fig. 69) meet the requirements in a satisfactory manner. The efficiency of the gingival marginal burnishers is increased by grinding the lip of the instrument until it is about one-third its original length.

Technique of Burnishing Matrices.

The technique of burnishing matrices is dependent upon the material used and the thickness of this material. If thin gold is used for simple approximal and approximo-incisal cavities, the metal should be surrounded by goldbeater's skin or china silk, and forced into the cavity with pellets of spunk or cotton (Fig. 70). After the foil has been forced to the seat and to the axial walls of the

cavity it is then turned over the margins by wiping the metal toward the margins with a pledget of cotton and by pressing toward the walls of the cavity. After removing the goldbeater's skin or china silk the matrix is again inserted into the cavity and is then filled with paraffin and wax, which is forced gently toward the walls of the cavity with large burnishers. If the matrix is for an approximal cavity a strip of rubber dam is then placed over it with the wax in position and used as a means of swaging the foil to the margins (Fig. 71). After this the matrix is removed and the wax absorbed from it by placing a roll of cotton over the wax and heating it to its melting point. The cotton absorbs the molten wax and leaves a clean matrix.

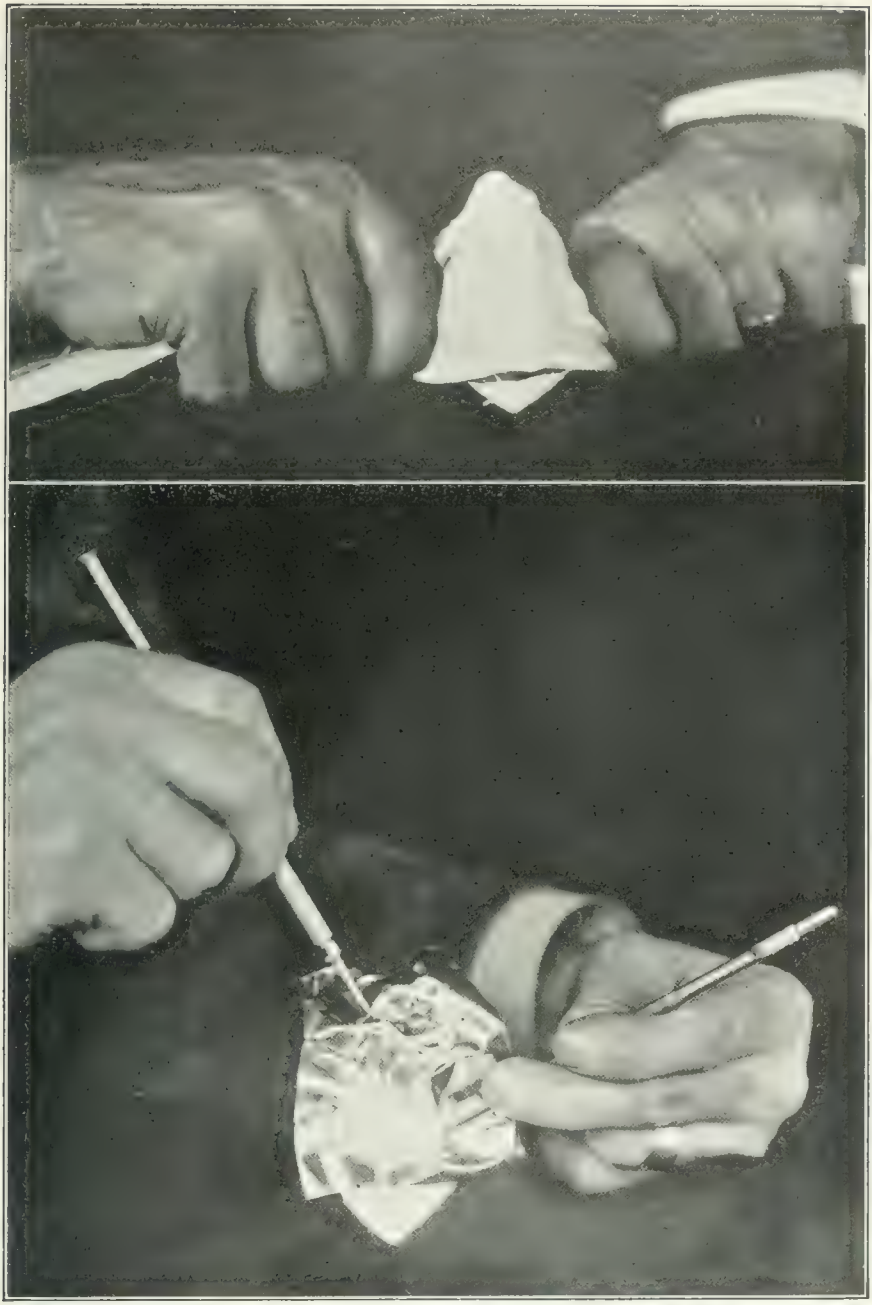
When matrices are constructed of gold, platinous gold or platinum foil 1/2000 of an inch or heavier, most of the burnishing should be done directly on the metal with proper burnishers (Figs. 66 to 69). A piece of foil large enough to be held between the thumb and forefinger without interfering with the burnishing is placed over the cavity (Fig. 72). It is pressed into the cavity with a pledget of cotton; then with a large ball burnisher the metal is gently and gradually forced into the cavity, when smaller burnishers are used to gradually conform the foil to the seat. A strip of heavy rubber dam is then placed over the matrix, which is filled with tightly rolled cotton, and with direct pressure, the foil is turned over the margins of the cavity and the adjacent surfaces of the tooth, to prevent wrinkling of the matrix at the margins (Fig. 71). The matrix is now withdrawn from the cavity and the surplus metal is trimmed so that its edges will rest uniformly on a flat surface. It is now replaced and held firmly against the walls of the tooth with the thumb and forefinger and reburnished with a series of ball burnishers beginning with the largest, then continuing with smaller ones until the matrix conforms to all walls of the cavity and its margins (Fig. 73). The margins of the matrix are now burnished with the special marginal burnisher (Figs. 68 and 74) until the foil is closely conformed to the cavity margins. If the cavity extend to or beneath the gum the foil may be made to overlap and conform to the gingival margin by the use of a pair of special gingival marginal burnishers (Figs. 69 and 75). The matrix should now be annealed, then placed into the cavity and filled with gum camphor or hard wax. If gum camphor is used, a piece of gum that will fill the cavity is placed into the matrix and is used as a means of swaging it to the walls and margins of the cavity with the assistance of blade burnishers. A piece of heavy tape is then placed over the camphor and pulled directly toward the margins of the cavity (Fig. 76). This swages the metal under direct and uniform pressure and forces the matrix



FIGS. 70 AND 71.

FIGS. 72 AND 73.

FIGS. 74 AND 75.



FIGS. 76 AND 77.

to conform to the margins of the cavity at all points. If hard wax is used in place of camphor it should be made slightly plastic, then immersed in cold water to destroy its adhesiveness. It should be manipulated between the thumb and fingers, which should have been previously immersed in cold water. A small ball of wax is then placed into the matrix and forced into place with a blade burnisher. The tape should be moistened before placing it over the wax for the final swaging. The wax has an advantage over camphor in that it will adhere better to the walls of the matrix, thereby assisting in the removal of many matrices. Either camphor or wax may be burned from the matrix, leaving no residue.

Fig. 78.

The following additional details in the technique of forming matrices for larger approximo-incisal cavities with irregular marginal outlines should be considered. In case the margins present one or more reverse curves, the matrix should be burnished differently from the method used in those cavities in which the marginal outlines form a straight line. After the foil is irregularly burnished to the cavity it chould be conformed to the margins of the step with the shank of a small ball burnisher (Fig. 77). The matrix is then filled with hard wax and the foil turned over the margins of the cavity in the tooth with rubber dam. The force should be directed in such manner that uniform pressure is made on the foil to prevent its overlapping at the margins. The foil should then be forced into the reverse curves with the marginal burnisher. The matrix should now be trimmed so that its edges will rest uniformly on a flat surface. It is then annealed and adjusted to the cavity for final swaging. This is done by filling the matrix flush to the margins with hard wax (Fig. 78)

and swaging with tape. Care should be exercised to exert uniform pressure on the margins of the matrix during the process of swaging (Fig. 79).

It is probable that the seat of the matrix will be torn during the process of burnishing (Fig. 80 A), but such tears in the seat of a matrix do not affect its efficiency. Sometimes, moreover, the matrix may tear

Fig. 79.

at some point along the labial or lingual margins (Fig. 80 B). If this tear is small, it need be considered of no consequence. Large perforations in the region of the seat and small ones along the margins of the matrices for high fusing porcelain may be bridged before applying the porcelain by painting the cavity side of the matrix with a thick solution of shellac (Fig. 81 A), which prevents porcelain from flowing through the perforations, and burns from the matrix without leaving a residue. It is advisable to coat a perforation at the margin before each application of the porcelain in order to insure a smooth margin of porcelain after the matrix has been removed.

Because of the irregular formation of some approximo-incisal, and the inaccessibility of many approximo-occlusal cavities, the method of first swaging the foil into a model of the cavity is particularly indicated. Although many porcelain workers construct all inlays by swaging matrices into models of cavities, the author believes it is possible to construct more accurately fitting inlays for simple approximal and most of the approximo-incisal cavities by burnishing the foil directly into the cavity or by swaging first into the model and then burnishing the foil into the cavity. However, he believes more accurately fitting matrices may be constructed for

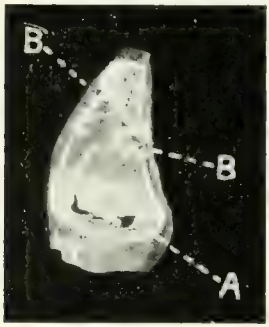


FIG. 80.

FIG. 81.

large approximo-occlusal cavities by relying wholly on swaging into models because of the difficulty with which matrices are burnished into such cavities in the mouth. Still, he admits that it is almost impossible for him to construct absolutely accurate models unless they are made under pressure, and he believes that, with few exceptions, the models not constructed under pressure, as made by most dentists, are not absolute positives of the cavities which they represent.

Impression Methods.

There are many materials used for taking impressions of cavities. Those which have received the most consideration are: Dental lac, modeling compound, Klewe & Company's impression material, gutta percha and the oxyphosphate cements. Dental lac and modeling compound are used probably more than all of the other materials. They have the advantage in that they are more easily manipulated and require less time for taking the impression. Modeling compound should be made plastic by moist, and the other materials by dry heat. An impression tray, the design of (Fig. 82) makes a valuable adjunct

for confining the material to the desired location. It not only prevents the impression material from crowding into the interproximal space, but holds it to proper conformation along the axial walls of the cavity. These trays are constructed from a stock of copper or German silver thimbles and may be made to conform to the tooth for each operation with a loss of but very little time. The tray should be so fitted that the length in the occluso-gingival direction will permit its edge to extend about 1 mm. beyond the gingival margin of the cavity. The handle (Fig.

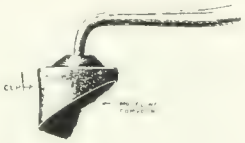


Fig. 82.

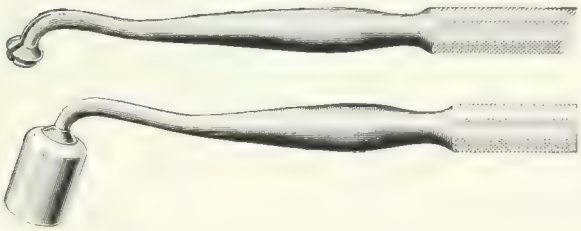


Fig. 83.

83) which should be used with the tray permits it to be manipulated more easily and prevents obstruction to view during the process of fitting.

When any of the above mentioned materials are to be used for taking the impression, a small pellet of the material is made plastic and placed in the impression tray. The material should be passed through the flame to give its surface a glazed-like appearance. It is then pressed into the cavity, which is moist, with the pressure directed on a line with the axis of the tooth, and then chilled quickly and removed. Gutta percha does not give so sharp an impression as modeling compound. It requires more heat to make it plastic and more pressure to force it to the walls of the cavity. Its use may be indicated, however, in those gingival cavities extending beneath the gum margin, where a moderate amount of force is required to press the gum from the cavity in order that an accurate impression of the gingival wall may be obtained.

If oxyphosphate of zinc cement is used for an impression material it should be mixed to a putty-like consistency, kneaded between the thumb and finger, and then placed in the impression tray. The material should be forced into the cavity, in which it should remain until the cement has thoroughly hardened. The impression may fracture or change its form if the cement is removed while it is in a semi-plastic state.

Models of Cavities.

Models of cavities may be made in amalgam, oxyphosphate of zinc, inlay metal (a preparation prepared by the S. S. White Company, which is similar to Spence's metal) and low fusing alloys. Each of

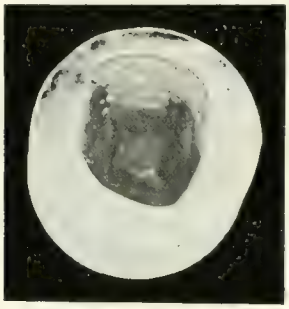


FIG. 84.

these materials has some advantages, and if used when indicated, will meet the requirements.

Models constructed of amalgam present a sharp outline and seem to be as accurate as it is possible to obtain them unless they are constructed under pressure. The advantage of accuracy is the only point in its favor. It requires from four to six hours for the amalgam to thoroughly set, and unless it is manipulated at the proper consistency it gives a granular surface over which the matrix is to be swaged. There is always an element of uncertainty regarding the accuracy of the amalgam model, and the operator can not be relieved of the suspense until he has separated it from the impression.

Oxyphosphate of zinc may be used for constructing models, but the difficulty of securing accurate models unless constructed under pressure causes the element of uncertainty to be an objection. There are, however, these advantages over amalgam: The model may be separated from the impression in a comparativly short time, and if it is faulty another one may be constructed without delay, and the operator is not required to wait several hours before the matrix can be swaged.

The inlay metal is manipulated differently from amalgam, or the oxyphosphate cements. It fuses at a comparatively low temperature, and is cast into the impression. It is largely composed of sulphur and graphite, and if overheated it ignites, giving off the disagreeable odor of sulphur. If the metal is permitted to burn, its composition is changed and its properties are affected. It gives a sharp casting, and models constructed of this metal are fairly accurate. Low fusing alloys, composed of tin, lead, bismuth and cadium, may be used for constructing models. They are particularly indicated in those cases where the matrix is to be burnished into the cavity after it has been swaged. They cast with a sharp imprint, and it requires but a few moments to construct a model with these alloys.

The technique of constructing models varies, and each material requires a method of constructing peculiar to it. If models are to be constructed of amalgam or cement without pressure, the impression should be invested with the impression of the cavity upward, in plaster of Paris to reinforce the frail walls (Fig. 84). This also gives a base which tends to hold the impression steady while the material for the model is packed into it. A rubber ring one inch in diameter and one-half inch long, is filled with plaster, mixed to a thick consistency, and then the impression is forced into the plaster so that all except the imprint of the cavity and the walls of the tooth are covered.

Amalgam Models. When amalgam is to be used for constructing a model, it should be mixed so that it has ample plasticity after a portion of the mercury has been expressed. It should be forced into the deep depressions of the impression with small flat-faced pluggers, and the excess mercury should be removed with cotton. The bulk of the impression should be filled by condensing the amalgam with large flat-faced pluggers. This prevents the "chopping" of the amalgam during the process of condensation and forces the excess mercury to the surface, which should be removed with pledgets of cotton or spunk.

Oxyphosphate Models. If oxyphosphate of zinc is used for a model it should be spatulated to a putty-like consistency and kneaded between the thumb and finger, until all air bubbles are excluded. The cement should be formed into an irregular conical shaped mass and forced into the impression with the thumbs and large burnishers. If the model is so constructed from an impression taken in cement, the impression should be coated with soapstone, and the cement used for the construction of the model should be of different color from that of the impression.

Dr. Roach's Device. Dr. F. Ewing Roach, of Chicago, has designed a device for making models under pressure (Fig. 85), which simplifies their construction and assists in obtaining more accurate models. The impression is invested in the base, which is filled with moldine (Fig. 86). The cement is mixed to a putty-like mass and packed in the impression, then the cylinder, which is

FIG. 85.

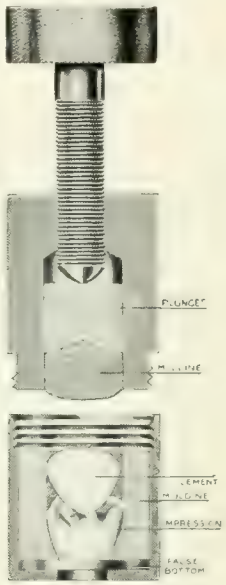


FIG. 86.

filled with moldine, is screwed to the base and the plunger forced toward the base by screwing it in the cylinder. This makes constant and uniform pressure on the model while it is setting, thereby giving a sharper imprint than can be made by packing the material into the impression without constant pressure.

The Author's Device. When the model is to be constructed of the inlay metal or of a low fusing alloy, the impressions should be oiled and invested in moldine, imbedding all except the impression of the cavity and the walls adjacent to it. The ring of a swaging device (Fig. 87), which acts as a matrix for the molten metal, should be placed over the impression with its larger opening downward, and with the center of the ring over the center of the impression. Care should be exercised to prevent the inlay metal from becoming overheated, and in case it ignites the flame should

be extinguished immediately. The metal should be permitted to cool until it begins to crystalize around the edge of the ladle, then it should be poured into the impression, which has been oiled, through the smaller opening of the ring. If a low fusing alloy is used it should be heated over the flame until only a portion of the metal in the ladle is molten.

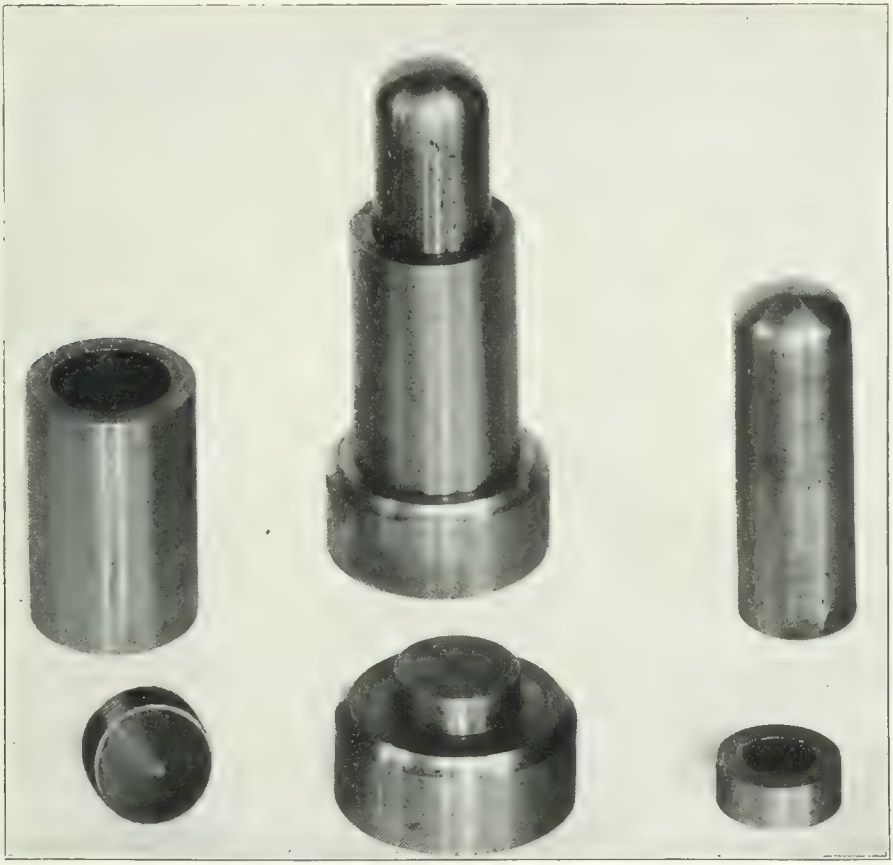


Fig. 87.

As soon as the mass becomes liquid it should be cast into the impression by the same method as that employed for casting the inlay metal. In either case the impression should be removed immediately from the moldine and immersed in cold water. After the metal has thoroughly crystalized the impression is removed from the model by making it plastic. If small particles of the impression material adhere to the model these may be removed by saturating a pledget of cotton with alcohol or chloro-

form and rubbing it over the model. The ring which acts as a matrix during the process of casting the model so shapes its base that no further investing is required for swaging (Fig. 88 B and C).

The best soft plungers for swaging matrices into models are made of velum rubber, and these are so constructed that they press the foil from the center of the cavity to the margins (Fig. 89). They are constructed by forcing a piece of plastic modeling compound through the cylinder

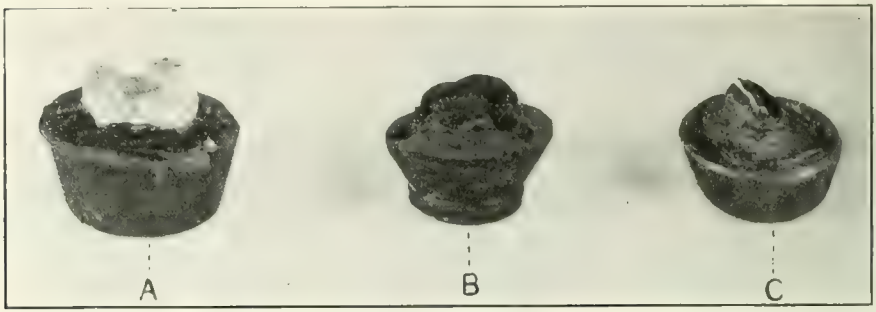


Fig. 88.

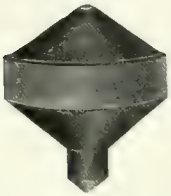


Fig. 89.

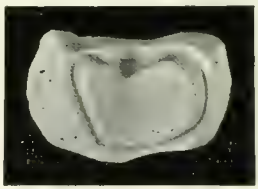


Fig. 90.

of the swaging device with the metal plunger. The end that conforms to the face of the plunger remains unchanged while the opposite end is carved to any desired form. The modeling composition is then invested in plaster of Paris so that a mould will be constructed in two sections. After the modeling composition has been removed the mould is filled with velum rubber and vulcanized at a temperature of 310° F. for ninety minutes.

Swaging Matrices in Cavity Models.

The technique of constructing a matrix by swaging it into the model of the cavity is as follows: Invest the model in the ring of the swaging device in modeling composition so that the center of the cavity is equidistant from the periphery (Fig. 88 A). An-

neal the foil, then force it into the model of the cavity with ball burnishers. After the foil has been irregularly forced into the model it should be swaged gently with the velum rubber plunger. Remove the matrix from the model and trim to proper size; dust the model with soapstone, applying it with a camel's hair brush, and blowing away the surplus. The

Fig. 91.

matrix is placed into position and given the final swaging. The most delicate step of the operation is removing the matrix from the model, as this must be done in such manner as to prevent distortion.

Swaging Matrices over Impressions.

The method of swaging matrices over impressions of cavities has some followers, and the advocates of this method claim that they can construct more accurately fitting inlays. However, experiments show that the thinnest film to which a layer of cement can be squeezed, under pressure equivalent to that applied in setting inlays, is not much less than 1/2000 of an inch in thickness, so that the inlay, when set with cement, will not absolutely fit the cavity. If simple approximal, approximo-incisal or approximo-occlusal cavities are pre-

pared with proper marginal form, there will be no perceptible difference in the fit of the inlay, whether it is constructed in a matrix, burnished into the cavity or swaged over an impression of the cavity.

The method of constructing matrices over an impression is particularly indicated for cavities on the labial or buccal surfaces of teeth, or in any form of cavity known as a four-wall cavity. Such forms of cavities can not be prepared so that the matrix can be burnished into the cavity and the inlay compensate for the space of the matrix unless it be constructed with frail margins of porcelain, which lack edge strength, and are so thin that a change of color is noticeable along these margins.

The technique of constructing matrices, by swaging over an impression of the cavity, is as follows: The impression should be taken in cement, which should be mixed to a thick consistency. It should be formed into an irregular conical shaped mass, forced into the cavity and permitted to remain under pressure until it has hardened. To take an impression of a labial or buccal cavity extending beneath the gum margin, mix the cement to a thick consistency. Then with some form of retractor, crowd the gum back and force the cement to place with the fingers, holding it in position until it has hardened.

The impression (Fig. 90) is invested in the ring of the swaging device. A piece of platinum foil not thinner than 1/1000 of an inch is placed over the impression and partially swaged with the velum rubber plunger. The foil is then trimmed to proper shape and placed over the impression and burnished, at the angle formed by the cavity margins and the surface of the tooth, with steel burnishers (Fig. 91). The matrix is then removed and the impression dusted with soapstone; then the matrix is reswaged with a velum rubber plunger which has a flat face. It is then carefully removed without changing its form.

Refitting Matrices. The method of swaging the matrix into a model of the cavity and then burnishing it directly into the cavity as a subsequent operation is particularly indicated for those approximo-occlusal cavities where the cavity extends far beneath the gingival margin and involves a large portion of the occlusal surface. The matrix may be swaged of gold or platinum 1/500 of an inch in thickness. If a heavy material is used for the matrix, there is less danger of warping during the process of fusing. The matrix, however, should become a part of the inlay. After it has been swaged to conform to the model, the foundation of the inlay should be fused, then the matrix placed into the cavity and burnished to conform to the cavity margins. The matrix should be trimmed close to the margins of the cavity after the final fusing, but the final finishing of the margins should not be accomplished until after it has been set.

Chapter V.

Some Phenomena of Color in Porcelain Inlay Work.

The phenomena of color should be studied in a theoretic and practical manner, and the sources of light should be considered. Light has been defined as that form of radiant energy that acts on the retina of the eye and renders visible the objects from which it comes. An object is visible, either because it gives out light of itself (self-luminous), or because it reflects light from its surface (illuminated). The light of the sun or the flame of a lamp are examples of self-luminous bodies, which emit luminous rays in all directions. Light emitted from the sun is said to be white light, while that from artificial sources is said to be colored light. Sunlight is represented by white, while darkness is represented by black.

Color Defined.

Color is a sensation produced in a variety of ways, but pre-eminently by the action of light on the retina. The specific effect produced depends upon the character and combination of rays that reach the retina. The source of color is light, and it is lost or destroyed by darkness. Colors are divided into inherent and transient. Inherent colors are material or colored substances such as the pigments used by the dyer, painter, etc. Transient colors are those formed by the decomposition of light, such as those of the rainbow or the prism.

Some of the phenomena of light which assist in producing colors from pigments are absorption, transmission, reflection, and refraction. If a pigmented transparent body absorbs certain colored rays and transmits others, it will appear to be colored from the combination of the transmitted rays. A translucent body transmits, reflects, and absorbs rays and its color is determined by the quality of light reflected or transmitted. If light penetrates a short distance into a body, and is then reflected, its surface generally appears to have the colors of the reflected rays. Light is not transmitted by opaque substances, but the rays are either reflected or absorbed. When, therefore, light is incident upon an opaque body, it is wholly excluded from the opposite side. A light beam passing from one medium into another of different density is bent or refracted at the boundary plane between the two media. This deviation

of light waves in passing from one medium to another varies with the media and with the angle of incidence. Reflection usually accompanies refraction, and this phenomenon causes much of the uncertainty of results in applying colors.

When red, orange, yellow, green, blue and violet rays are combined in proper proportions, white light is formed, but when red, orange, yellow, green, blue and violet pigments are properly mixed black is produced. The first phenomenon is caused by the combining of colored light by a process of addition of rays, and the second is a result of adding pigments and subtracting light, for all the rays transmitted are absorbed or quenched by another pigment.

While all pigments have the power to reflect or transmit light, it is their power to absorb certain rays that assists in producing color. The colors of stained glass, porcelain, etc., are examples of this phenomenon. Such pigments as those used by dyers and painters are but representatives of colors; they imperfectly represent the primary colors. There are no pigments which produce colors that absolutely match the primary—red, yellow and blue. Red pigments reflect or transmit red, yellow and orange rays and absorb violet, blue and green rays. Yellow pigments transmit or reflect red, orange, yellow and green rays and absorb blue and violet. While blue pigments transmit or reflect green, blue and violet rays and the remaining rays, red, orange and yellow, are absorbed by these pigments.

If pigments could be obtained which truly represented each primary color, the laws of color could be more accurately illustrated; but since this seems impossible the colorist is beset with many difficulties. Pigments are very often obtained which nearly represent their respective primaries, but when these are mixed they do not produce a good secondary color, because of such differences as transparency, opacity, chemical components, etc.

Combining Colors. One of the most prevalent theories of color formation from pigments treats red, yellow and blue as the primary colors. According to this theory the many colors used by colorists may be made from these three. When two of these primary colors are combined secondary colors are formed. Red and yellow, for instance, give orange; red and blue yield violet; and yellow and blue produce green. By combining the three primary colors so that complete absorption of light takes place, black is formed. Those colors produced by the three primaries are termed tertiary colors. The third primary color, however, does not produce a new hue, but merely saddens the other two by forming a certain amount of gray or black in the combination. They are often termed the dulled or broken tones of

the primaries or secondaries. Orange and violet produce a reddish brown. Green and orange combine to form a yellowish brown. Green and violet produce a bluish gray.

Qualities of Colors. Colors have three principal qualities known as hue, purity and luminosity. These are generally spoken of as constants. The excessive predominance of one color over another gives the hue to that color and the greater this predominance the stronger will be the hue, *e. g.,* when blue and yellow are mixed green is produced. If yellow predominates, the green will have a yellowish blue.

The purity of a color is its lack of mixture of white or black, or any of the colors. These not only weaken the color but change its character. This can be shown by adding white porcelain to yellow. The yellow is not only diluted but tends to take a different hue.

The luminosity of a color is measured by the amount of light reflected to the eye, and is, therefore, independent of hue or purity. The most luminous color is yellow, while the least luminous is violet; between these extremes are all the intermediate degress of brightness. In those teeth where light yellow and blue predominate they appear more translucent, because they reflect and transmit the rays; while in those teeth where gray and brown predominate they have a somewhat dull appearance, because their power of reflection and transmission of light is not so great, as more of the rays are absorbed on the surface.

Gradations of tint, shade and hue are numerous, according to the power of perceiving them, and this power greatly varies with different individuals. Much of the success in coloring depends on the keen and delicate perception of gradations. One totally unfamiliar with the principles of color formation and whose eye is not trained to detect the delicate hues, rarely sees all of the gradations of color in a tooth, while one with a trained eye will distinguish hues of colors that are wholly imperceptible to another.

Pigments Used in Porcelain. The pigments most commonly used in the manufacture of dental porcelain are precipitated gold, platinum, purple of Cassius, the oxids of gold, titanium, manganese, cobalt, iron, uranium and silver. The colors produced by the use of these pigments in varying proportions are red, yellow, blue, green, brown and gray. In referring to red, yellow and blue, used by the porcelain worker, it must be borne in mind that only the hues of these colors are used. But for convenience we shall refer to their hues as the colors.

Red is used extensively by inlay workers. Still all gum enamel frits are tints of red. It may be added to brown to increase its luminosity. Its

tints should be used on the labial or buccal surfaces in building that portion of the inlay which may extend rootward beyond the gingival line.

Yellow, the most luminous of the colors, is the one most closely allied to light, and it is the one used most by the porcelain inlay worker. It should be used to form the foundation of most inlays. It adds brilliancy to brown and gray when added to them. Yellows of a greenish hue tend to lose their luminosity in yellow light, while yellows of a reddish hue are most luminous. Two yellows in their deeper tones may match each other perfectly, but when diluted to give lighter tints they may differ quite widely; one may be of a greenish hue, while the other may tend toward a red.

Blue is used to build the body of the incisal and occlusal portion of inlays for those teeth with blue incisal edges or cusps. It may be added to grays with a bluish hue to intensify them. There is a variation in tone from blues with a greenish hue to those with a reddish hue. The former with a greenish hue are more luminous and appear to be more translucent.

Green is seldom used alone, but it may be added to yellow to give it a greenish hue and to blue to increase its translucency. Browns should be used to build the gingival portion of some inlays and also for the body of inlays for discolored teeth having a brownish hue. Grays are principally used to build the middle and incisal and occlusal portion of these teeth with a grayish hue. They are also used to sadden yellows and blues.

The various hues of colors are produced by mixing pigments in various proportions or by superimposing a layer of one pigment upon another. The intensity of a color is controlled by the intensity of the pigments used and by the thickness of the layers of pigments. Two or more shades of a color can be made of the same porcelain by varying the thickness of the body. Knowledge of this fact is important in the application of porcelain. For, after porcelain has been applied and fused, it is often found that the color is changed. The trouble may arise from several causes. The layer of enamel may be so thin that it is highly translucent and light from the underlying layers is readily reflected through it. The underlying layers may be constructed of porcelain whose pigments are so intense that they cause the inlay to appear too dark after the final layer of enamel has been applied.

Method of Learning Color Combination.

If the beginner is not familiar with the formation of colors, he should purchase a water color outfit, consisting of the three primary colors, red, yellow, blue, and a drawing book with white leaves. He should first study the variations of a color produced by decreasing the thickness of the layer of pigment. This is done

by saturating the brush with the desired pigment, then varying the thickness of the layer on the paper. The next experiment should be to make binary combinations. First, red and yellow are mixed in varying proportions, showing orange with a reddish hue and orange with a yellowish hue. The same experiment is made with red and blue, showing the variations of the hues of violet from violet with a reddish to violet with a bluish hue. Yellow and blue are next mixed, showing the variations in green from a bluish to a yellowish hue.

After the experiments of producing secondary colors by mixing pigments have been completed, the next experiment should be to produce the same colors by applying a layer of one primary color to the paper, and, after this has dried, placing the second primary over the first layer. When the experiments with the binary combinations have been completed, experiments with the tertiary combinations should be made. Two primary colors are mixed and the third primary is added in varying proportions to produce browns and grays. Black can also be made from the three primary colors by mixing them in proper proportions. At this time black and white pigments should be introduced; and the process of tinting by diluting pigments with white, and saddening colors by the addition of black, and combining black and white to make grays should be studied.

After experimenting with water colors, the beginner should carry on a line of experiments in colors with porcelain. For this work he should use yellow, blue and dark pink. It has been found that those manufactured by the S. S. White Dental Manufacturing Company especially for this purpose are the most satisfactory. While these colors do not match the primary red, yellow and blue, and do not meet the requirements in an entirely satisfactory manner, they enable one to obtain results that prove that the formation of colors from pigmented porcelain depend upon the same phenomena of color formation that are involved in the formation of colors from other pigments.

Method of Learning to Combine Porcelains.

A suitable mold should be constructed, in which the various combinations can be made. The beginner should mold and fuse various combinations of red, and yellow, and blue in varying proportions. After studing the phenomena of color formation in porcelain, a shade guide for inlay work can be made by combining porcelain powders in definite proportions.

Dr. V. Walter Gilbert, in his "Notes on Dental Porcelain," offers the following suggestions to beginners: "The best way for a beginner in porcelain work, therefore, is to experiment in the mixing and fusing of colors before he attempts the construction of a practical inlay or crown.

This work can be made immediately profitable in experience, for he will need a set of sample shades made from the materials he is to work with. He will find greater satisfaction in working to shades of his own compounding than with any fixed samples of mixes supplied by the manufacturers of the material. Of course, in making these buttons he will need to note carefully the exact proportions in each experiment. He will thus have an invaluable record, and every experiment will serve as a guide in his future practical work; the failures advising him what to avoid, the successes pointing the clear way to useful results."

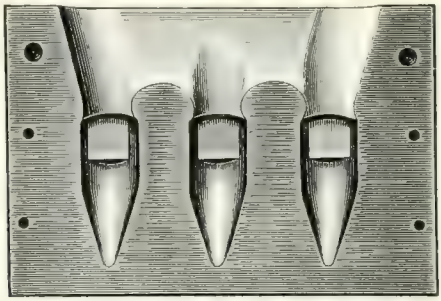


FIG. 92.

Making Shade Samples.

A practical method of making new shades from the powders furnished by the manufacturers is to carve a suitable form in plaster, wood or metal, and from such a form make a mold with Melotte's metal. (Fig. 92.) By the use of such a mold new shade forms of uniform shape and size can be made.

Weigh out varying proportions of the different colored powders and mix with water to the consistency of dough, then oil and press it into the mixed porcelain. If the mold has been properly made, an imprint of the desired form will be made in the porcelain, and this when properly trimmed and fired will record the new shade so produced.

Care should be taken to record the various mixtures so that they may be duplicated at any time. The keeping of such records may be made in this way—using the letters of the S. S. White Dental Manufacturing Company's porcelain to illustrate: Three parts of A added to two parts of B will produce a new shade, which can be designated as No. 1, or by any name desired, and can be recorded thus: 3A+2B=No. 1. It will be observed that by making shades as here suggested there is no limit to

Illustrations 92-96 from "Notes on Dental Porcelain" by courtesy of the author, Dr. V. Walter Gilbert, and the S. S. White Dental Manufacturing Co.

the number of shades that can be produced. To illustrate still further: A is gray, while G is white or colorless, used principally as a modifier to get gradations of other colors.

Make mixture of varying proportions of A and G, thus: 9A+1G; then another mix 9A+2G, and so on. By combining each of the other shades in this way with G, two hundred and fifty gradations will be produced, and this is only the beginning of the possible combinations.

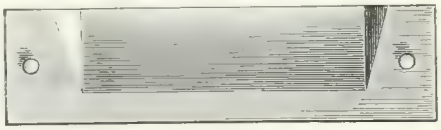


FIG. 93.

FIG. 94.

FIG. 95.

FIG. 96.

The method just described answers very well if the texture of the porcelain is coarse like that of the Allen and Close bodies; but if the texture is fine, like that of most porcelain now used, there will be more or less difficulty in removing the porcelain from the mold. This difficulty is due to the close adaptation of the fine particles of porcelain.

When making new shade samples from a fine texture porcelain, the same mold (Fig. 92) can be used, but the method of using must be changed. In place of mixing the porcelain with ordinary water and pressing the mold into the porcelain, it is advisable to use gum water and

press the porcelain into the mold. The mold containing the porcelain can then be placed in a suitable ladle and melted, thus delivering the porcelain shade sample in a perfect condition. Another mold can be made in a few minutes by flowing metal over the original metal form.

Pouring Method.

Another method of making individual shade samples may be described as follows: A metal mold, consisting of four parts, can be readily constructed so that the mixed porcelain can be poured or dropped into it and the mixing medium absorbed. Fig. 92 represents the front face of such a mold; Fig. 93, the pouring gate; Fig. 94, the part which carries the pins for making the holes in the finished shade samples; Fig. 95, the back face, which holds the absorbent plaster. To make sample pieces in a mold of this description it is necessary to thoroughly oil all working faces, hold the parts together with a clamp of some kind, and then drop the thinly mixed porcelain, drop by drop, into the mold, being careful not to clog up the opening. When the mold is filled, put it aside until the porcelain sets; then open the mold and gently remove the porcelain castings (Fig. 96). When the plaster becomes saturated with the mixing fluid, knock it out of the frame and pour a new back.

Matching Human Teeth with Porcelain.

One phase of inlay work which will always be perplexing is the difficulty in obtaining colors that accurately match the natural teeth. The enamel is a hard dense substance, presenting a glazed-like appearance, which causes it to be almost transparent. The dentin, on the other hand, is a porous-like substance which prevents the light from being transmitted freely and causes it to be but slightly transluscent. When we consider that teeth are composed of both organic and inorganic materials with a variation in their density, and that they are colored with pigments peculiar to them, we can readily understand how difficult it is to match tooth structure with a substance inorganic in composition, differing in density, and colored with different pigments.

In discussing this point Dr. C. N. Thompson, in *Dental Cosmos*, May, 1907, says: "A study of the normal tooth reveals the fact that its exact reproduction is impossible, yet to restore tooth-structure in appearance with porcelain without due consideration for the details of the make-up of the normal tooth is a mistake, for an examination of a cross section of the natural tooth reveals the enamel nearly opaque. Compare this with a cross section of a porcelain tooth, and it is not hard to discover the reasons for some of our difficulties, as well as to know that there must be method in our efforts if we would secure results.

"Dentin is so nearly opaque that it transmits light but feebly. Its opacity seems to be due, as much as to anything else, to the condition of

its external surface, which is without glaze—under the magnifier it seems rough, like fine sandpaper. The external surface stops the light as do crushed transparent substances generally—as, for instance, common salt —for the reason that the rays of light are so often reflected among the particles on the surface that they are scattered into a multitude of crossed reflections that appear white, and therefore can not enter. Thus it follows that whatever surface will not admit light will also refuse to allow a reflected shade to pass; consequently if the dentin can be restored with a very high-fusing porcelain that becomes densest before it glazes, that presents a vitreous surface resembling sandpaper, and of the color of dentin, we have produced a foundation for the filling that will not absorb sufficient light to cause a shadow, and which, if not glazed by a subsequent baking, will still retain the power to arrest transmitted light, no matter how the colors and enamel are laid on afterward."

Another difficult problem is the formation of a shade. A shade for the purpose of this work may be defined as a deficiency of light within an illuminated region, caused by the interception of light by some body, or a condition produced by a reflected light. When the light is incident on the teeth or lips, it is partially excluded from all or a portion of inlays in some of the teeth, and this causes the inlay to appear much darker. This fact should be considered when selecting colors for an inlay. The color of the tooth should be studied with the incidence of light at different angles and with the lips partially covering the tooth. In selecting colors for inlays in the distal surfaces of laterals and cuspids, the hues of the color should be lighter than for inlays on their mesial surfaces. If a porcelain inlay is placed in approximation with a gold filling, it will appear darker because a portion of the reflected shade from the gold will be absorbed by the porcelain, then returned to the surface of the inlay and reflected to the eye, which gives to the porcelain a saddened appearance.

Influence of Cement on Color.

A change in color is often noticeable when an inlay is cemented into place. The inlay may be a good match when the incidence of light is at such an angle as will permit its transmission. But when the angle of incidence is changed, some portion of the inlay may appear a different color, caused by the formation of a shade. In this phenomenon the cement is the chief factor of the color problem. If it were transparent, it would not prevent the passage of light through the tooth. If light penetrates a short distance into a body and is then reflected, the surface generally appears to have the color of the reflected rays. But since light is not transmitted by an opaque substance, the rays

are either reflected or absorbed. Whenever light is incident upon an inlay, it is excluded from the dentin, on account of the layer of cement, which forms an opaque body, and the color of that portion of the tooth and inlay which is in contact with the cement may differ from the other parts because of the unequal absorption and reflection of the rays.

Regarding reflected shades, Dr. Thompson, in the same article, says: "All illuminated bodies scatter or reflect light, and are distinguished from each other by the kind and amount of light they send to us, their power of selective absorption and surface reflection determining the color. If the source of light be a point, as in the electric arc light, the shadow is sharply defined; if, on the other hand, it comes from a luminous surface, as the sun, the edges of the shadow are fringed and imperfect, due to the angular magnitude of the sun. For example, the shadows of minute objects disappear almost immediately in sunlight, whereas the same objects in the arc electric light cause a well-defined shadow for a considerable distance if thrown upon a screen. This explains why porcelain fillings are more conspicuous in artificial light than in sunlight, the shadows thrown appearing more definite.

When light passes from one optical medium to another, a portion of it is always turned back, *i. e.*, reflected. This partly explains why a highly glazed filling that does not appear correct may be improved by grinding or polishing. A slight roughening of its surface causes less direct exterior reflection, and although it thus renders the surface slightly more opaque, it renders the deeper coloring more prominent, because light is reflected regularly and more fully by a glazed surface."

Chapter VI.

The Selection and Application of Porcelain.

Building in Layers. Building in Sections. Mixing Colors. Technique of Applying Porcelain to the Matrix.

In selecting the colors for an inlay, note the variation of color in the natural tooth, in which three or more colors, or hues of colors, are usually found. If the tooth is a vital one, the foundation, which should be constructed of a coarsely ground porcelain and be fired only to a high biscuit, should be a hue of yellow. Dentin is but slightly translucent and transmits light feebly; it should be replaced with a porcelain which approximates it in density, and which presents an unglazed surface. Such porcelain will cause the diffusion of the transmitted light, and this will cause less light to be transmitted to the cement and less reflected light to be transmitted through the porcelain.

A study of the colors of the teeth should be made before the porcelain for an inlay is selected. While the color of a tooth is due mainly to its pigments, the thickness of the dentin and enamel and the density of these tissues, with their power to absorb, transmit, refract, and reflect light, are also factors. The colors of most teeth containing no foreign pigments are hues of yellow, blue, brown, and gray, with a yellowish or bluish hue.

The first point to consider in the selections of colors is the variations of hues seen in different sections of the natural tooth. Under normal conditions dentin, which forms the body of the tooth, is some hue of yellow. The color of the enamel varies, and the variation of the thickness of the layer of the enamel, in different sections of the tooth, gives it a variety of hues of colors. A careful study of the colors of a tooth shows that the gingival third is usually some hue of yellow, modified by a hue of brown or gray, that the middle third generally appears to be a gray, having a yellowish or a greenish hue, and that the incisal third usually has a predominance of blue or gray.

The enamels, or colors, which replace the enamel, should approach the colors of the tooth in their respective locations. The intensity of their pigments and the thickness of the layer of the enamel govern their intensity of color, and, in most cases, quite intense colors should be used. The enamels should be more fusible than the foundation and should be a porcelain of a finer grain.

Methods of Applying Porcelain.

There is a difference of opinion regarding the application of porcelain for inlays, and this has given rise to different methods of applying the porcelain in the construction. There are those who apply the enamel in layers; others who advocate building in sections; some who prefer to mix the colors; while there are still others who prefer to construct the inlay by using a mono-chromatic porcelain of a lighter hue than the tooth, and to color the cement with pigments to approximate the color of the tooth. The method of using porcelains of a lighter hue seems to have no advantage, except for labial cavities, and it is open to unfavorable criticism. It may be advantageously applied, however, in labial cavities where the angle of incidence is always such that some rays are feebly reflected and others partially absorbed by the cement. It seems hardly possible to construct inlays for inciso-approximal cavities, requiring two or more colors, by lightening the porcelain and coloring the cement to match the colors of the different sections of the tooth. Large inlays constructed in this way have a uniformity of color, which is objectionable.

Building in Layers.

The method of building inlays in layers is probably the most popular one. Enough foundation body to replace approximately the dentin and the lingual plate of the enamel should be applied and fired to a high biscuit. It should be built solidly into the matrix and contoured, allowing for shrinkage. If it is not the desired contour after it has been biscuited, more of the foundation body may be added and the firing repeated. The enamels are now applied and the shading is varied from the gingival margin to the incisal edge. In the application of the enamels care should be taken to prevent porcelains of different colors from mixing when applying them in their respective position. The colors should be applied separately and biscuited, then a uniform color should be applied over the entire mass and fused. If the colors are applied intensely enough to reflect through the uniform color, there will be a harmonizing effect that more nearly approaches the natural tooth structure in appearance, while each particular color preserves its identity. This method obviates the necessity for using porcelain of a lighter hue and adding pigments to the cement. It

also breaks up the uniformity of color so often noticeable when an inlay is constructed of a mono-chromatic porcelain.

Building in Sections. Another method is to build inlays in sections. The foundation is applied and fired to a high biscuit. The gingival third is covered with an enamel that has the same hue as the tooth in that location. In case this section of the tooth shows a hue of gray or brown, a thin layer of enamel of the required hue is applied and fired to a high biscuit before the enamel of the predominating hue is applied. The middle third is then covered with the enamel of the desired hue and hard biscuited. The incisal third is built with an enamel that approaches the hue of the incisal third of the natural tooth and fired to a hard biscuit, after which a uniform layer of a neutral color is applied and fused.

Mixing Colors. There are conditions, however, under which it is deemed advisable to mix colors in the construction of inlays. While this is not necessary in the greater number of cases, the author has found that the mixing of colors sometimes yielded better results than he could secure by other methods of application. Some colors may require modification. The yellows, for example, may need to be toned with the grays; the grays brightened by the addition of yellow; or the blues may be lightened by the admixture of green, or saddened by the addition of a gray.

In mixing two porcelains or in applying them in layers, it must be borne in mind that the resulting color is primarily due to the power of the combined porcelains to absorb or transmit light. When the two porcelains are mixed, or when they are applied in thin layers, the resultant color is that which is transmitted by both colors in common. When two colors, as blue and yellow, are combined, it is found that green is the only color that is common to both of them, and this is, therefore, freely transmitted or reflected; the others being absorbed. If a layer of blue is placed over a layer of yellow, the light, in passing through the blue porcelain, loses its red, orange, and yellow rays, which are absorbed, and are not, therefore, transmitted; while green, blue and violet are transmitted to the yellow, which absorbs the blue and the violet, leaving the green to be transmitted or reflected. The purity of the green is dependent upon the purity of the yellow and the blue, and by the thickness of the layers. When blue is used to build the incisal portion of an inlay, the yellow foundation should extend only to the point at which the blue is to begin; for the blue will have a greenish hue, if it is applied over the yellow. When yellows and blues are applied over grays or browns, the underlying colors have the quality of saddening the overlying ones, because the transmitted rays from the yellow and blue are largely absorbed by the gray or brown.

It has been found that the method of constructing inlays of two bodies differing in density and fusibility yields the best results. The

Fig. 97.

foundation should not only be a higher fusing porcelain, but it should be a coarser one than the enamels. The coarse foundation should be

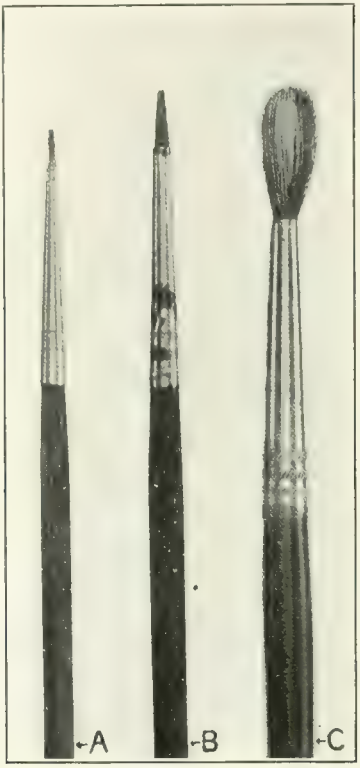


Fig. 98.

fired to a high biscuit and fused and then after the enamels have been added in their respective locations and fused the two porcelains give a more natural combination of color than can be produced by a single body. A glaze may be applied for the final layer, when the inlays are constructed for those teeth whose enamel presents a highly translucent and glazed appearance.

In applying the enamels over the foundation, each layer should be fired only to a hard or high biscuit, heating the porcelain just to the point of glazing at the final fusing. This is to be borne in mind because, in the process of applying the porcelain in layers and fusing each layer, the underlying layers will be slightly over-fused and somewhat lighter in color.

Fig. 99.

Technique of Applying the Porcelain to the Matrix.

The application of the porcelain to the matrix requires an instrument for mixing, applying, and carving (Fig. 97) and three sable brushes (Fig. 98). Enough of the bristles of the smallest brush should be cut away to make it very flexible (Fig. 98a). While there are a number of special carvers on the market, and many of them good, the author has found an instrument of the design shown in Fig. 97 to be the most useful. The blade serves as a spatula, the point of the carver may be used for applying the porcelain, and the instrument also meets the requirements for carving. The shank contains a series of circular grooves, which are useful in vibrating the matrix (Fig. 99).

It is not necessary to invest a matrix which is constructed of a material 1/1000 or 1/2000 of an inch in thickness. It should be held with a pair of lock tweezers during the process of applying and carving the porcelain (Fig. 100). The tweezers should grip the matrix at the point where it will offer the greatest resistance. It has been found that this point is at or near the linguo-gingival angle of a matrix for a single approximal or an inciso-approximal cavity. Care should be exercised, however, to hold the matrix in such manner as to prevent its distortion while applying and carving the porcelain (Figs. 101 and 102). Although the matrix has a limited degree of rigidity, it can not be handled roughly without changing its form.

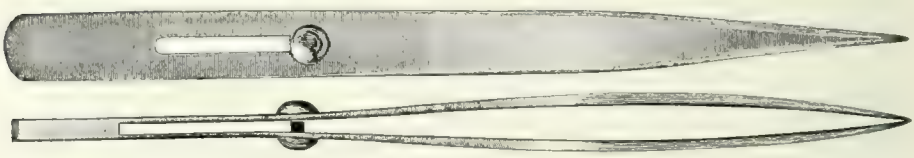
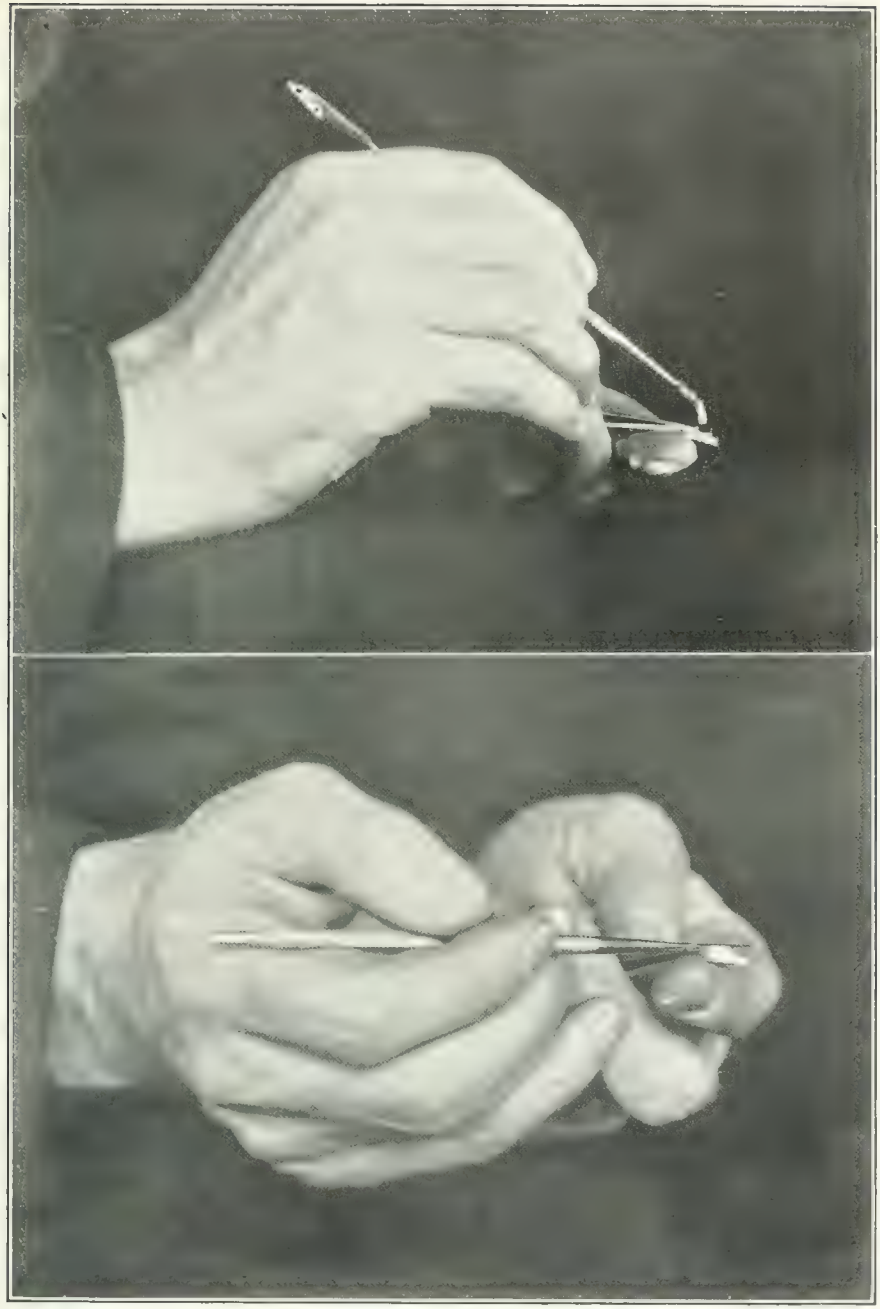


FIG. 100.

In case thin, pure gold is used for a matrix it is necessary to invest it (Fig. 64), to prevent its distortion during the process of applying the porcelain and to prevent its warping during the fusing. The investing cup should be made of some metal that does not readily oxidize, and that does not fuse at ordinary temperatures. The cup should be filled with powdered asbestos, which has been made plastic with water or alcohol. Apply a small quantity of the paste around the matrix and force it gently into the cup. Care must be exercised in investing the matrix that its side next to the asbestos may be supported at all points by the paste. This may be easily accomplished by lightly tapping the cup on the table. The operator should be careful, however, to prevent the asbestos from coming in contact with the margins of the matrix. After properly investing the matrix the investment is to be dried slowly until all steam has escaped, or until all alcohol has burned away. If the matrix is filled with wax before removing it from the cavity, and this is left in the matrix until the investing is finished, none of the paste could flow through any holes in the matrix. But in case there is no wax in it during the process of invest-



FIGS. 101 and 102.

ing, and some of the paste flows through the holes into the matrix, it can be removed with a brush moistened in alcohol. Any wax left in the matrix should be burned out at this stage of the operation.

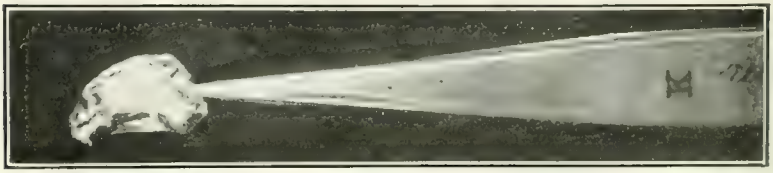


FIG. 103.

FIG. 104.

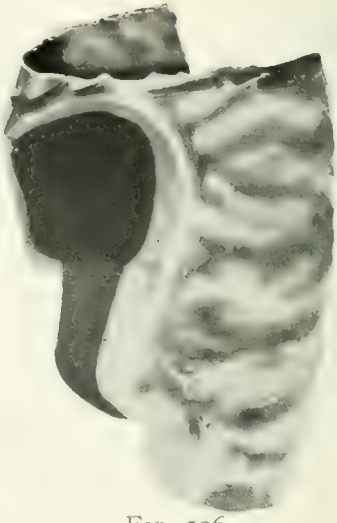


FIG. 106.

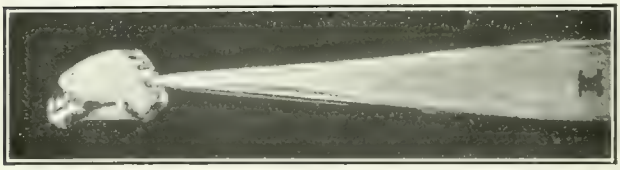


FIG. 105.

The author finds that he can obtain more satisfactory results, when using either high or low fusing porcelain, by building inlays in sections, and the method used by him for constructing approximo-incisal inlays is as follows: The foundation is properly applied to represent the contour

of the lost dentin (Fig. 103). If the porcelains are mixed with water they should be worked into a stiffer paste than when mixed with alcohol. This paste should be applied from the point of the carver (Fig. 101),

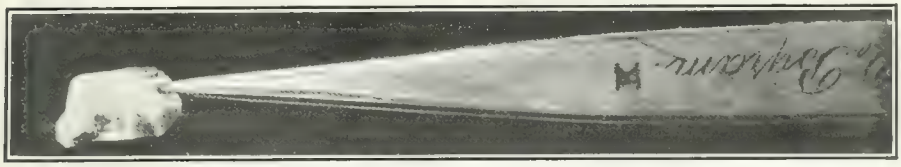


Fig. 107.

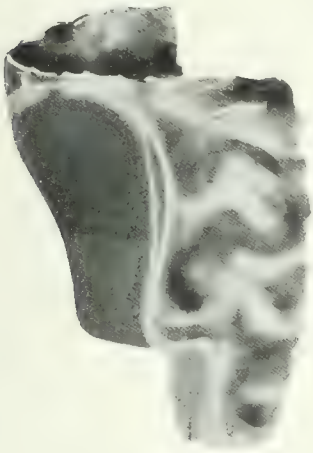


Fig. 108.

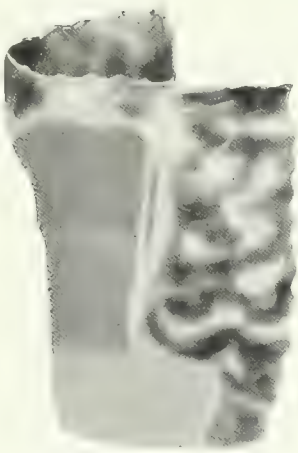


Fig. 110.

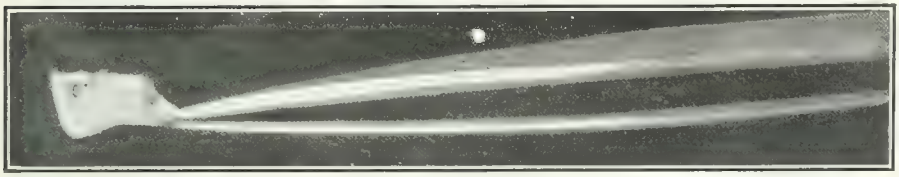


Fig. 109.

and flowed to place by drawing the shank of the carver across the tweezers (Fig. 99). Care should be exercised to prevent the porcelain from flowing to points other than where it is intended to have it flow. This is done by absorbing the moisture with small strips of blotting paper

or dry powder of the proper color. A surplus of paste should be placed in the matrix, after which the moisture should be absorbed by dipping the paste into the dry porcelain from the same bottle. It is then brushed with a large brush (Fig. 98c), and carved to proper contour (Fig. 103). If, after biscuiting, it is found that a sufficient quantity of foundation has not been added, another layer should be applied and fired to a high biscuit and it should then appear as in Fig. 104.

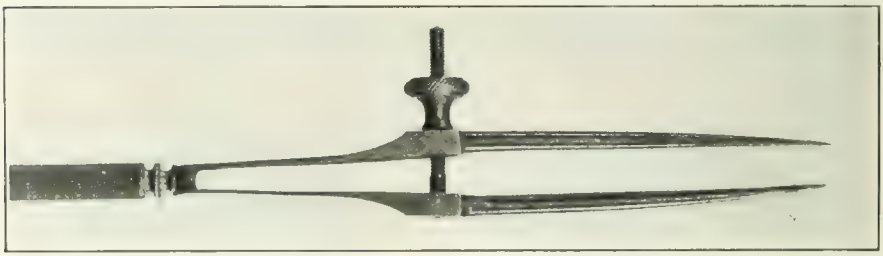
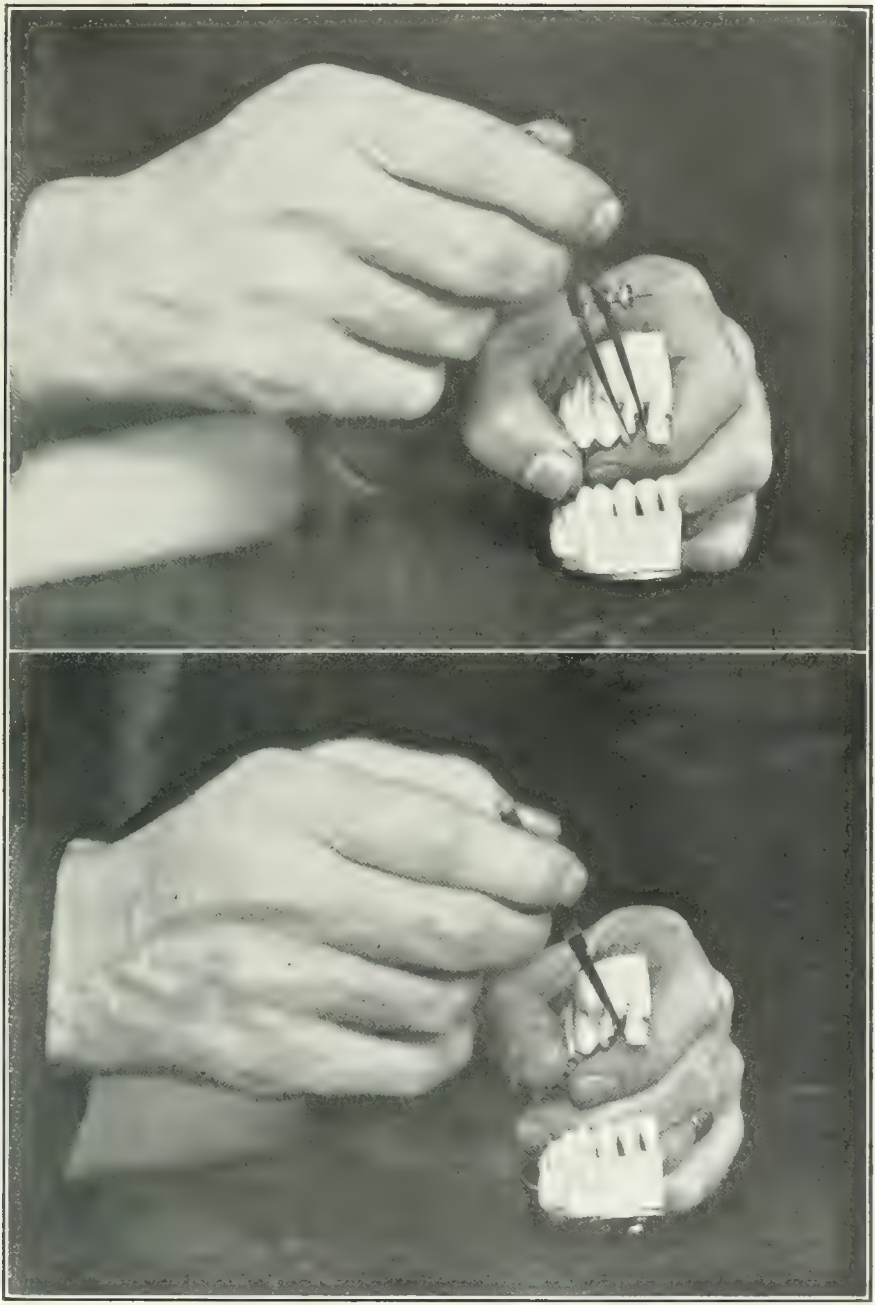


Fig. 111.

An enamel having the same hue of a color as the gingival third of the tooth is now applied to that portion of the inlay. It should be built almost flush with the margins of the matrix, but under no condition should it be made fuller; and no porcelain should be permitted to remain on the surface of the matrix. This result can be obtained by carefully brushing over the surface of the matrix toward the porcelain. After the gingival section has been applied (Fig. 105) and biscuited (Fig. 106), the middle section is built almost flush with the margin using the enamel having the desired color (Fig. 107) and biscuited (Fig. 108). The incisal third is now built to proper contour with an enamel that approaches the color of this section of the tooth (Fig. 109). After this has been biscuited, the inlay should appear as in Fig. 110.

At this stage of the operation the inlay may be tried into the cavity to ascertain whether it has the proper contour. It has been found that the contour of an inlay may be obtained by the following system of measurements: A delicate pair of calipers (Fig. 111) is used to obtain the distance from the axial wall of the cavity at the incisal edge to the approximating tooth (Fig. 112). After recording this measurement, the distance from the approximo-labio-gingival margin of the cavity to the approximo-incisal angle of the approximating tooth is measured and recorded (Fig. 113). While these measurements will assist the



FIGS. 112 and 113.

operator to obtain proper contour without trying the inlay into the cavity, a more accurate and better contour may be obtained by trying matrices for large incisoapproximal inlays into the cavities after the sections of enamels have been applied.

The entire mass is now covered and built flush with the margins of the matrix with a uniform layer of a neutral color and fused (Fig. 114), after which a layer of a glaze or a second layer of the neutral color of enamel is applied in such a manner that the porcelain does not overlap the margins and then fused (Fig. 115). If the details of this method of ap-

FIG. 114.

FIG. 115.

plying the porcelain are observed, the finished inlay will be flush with the margins of the cavity, thus preventing an overlapping of the porcelains.

It is probable that any porcelain that is to be applied to an invested matrix should be mixed with alcohol. It should be mixed to a cream-like consistency and flowed into position with the point of the carver or a small brush; it is not to be carved as the porcelain that is mixed with water. After moistening the matrix with alcohol, fill it almost to the margin with the paste that is to form the foundation of the inlay. The alcohol is then evaporated and the porcelain is fired to a high biscuit. After this firing the investment should be chilled by dipping the base of the cup in water, using care to prevent the investment from becoming moist. In case more foundation is required, a second application is made and biscuited. The enamels, approximating the colors of the various

sections of the tooth, are now selected and applied according to the method just described. It is better to apply them separately and fire them to a high biscuit, after which a uniform layer is spread over the entire mass and fused.

If the cavity on the labial or buccal surface extends beyond the neck of the tooth, and the gum has receded (Fig. 7), that portion of the inlay replacing the cementum can be constructed of pink porcelain to imitate the gum. The foundation should be applied as for other cavities on these surfaces. Select and apply an enamel in the gingival third that approaches the hue of the enamel. Then apply a gum enamel body to replace the cementum. It should be contoured to represent the festoon of the gum and then fused. This causes the inlay to be more deceptive than one constructed entirely of yellow porcelain.

Chapter VII.

Technique of Fusing Porcelain—Furnaces and Pyrometers.

The purity of colors of porcelain is partially dependent upon the accuracy of the fusing. The variation of heat of the muffle will cause differences in the shade of the porcelain. Under-fused porcelain is of a duller hue and less translucent; the blues appear lighter in color; the yellows, browns and grays appear darker than properly fused porcelain. Over-fused porcelain is much lighter in color and has more of a glass-like appearance.

If porcelain remain in contact with the maximum heat long enough, or if it is brought to the maximum fusing heat by repeated firing, it tends to form a glass-like mass. All the hues of a color from the normal to a light may be made from the same porcelain by increasing the heat above its maximum fusing point, but this is done at the sacrifice of strength. This explains why each layer of enamel should be fired only to a high biscuit, and all the enamels to the point of glazing only at the final firing.

The method of firing porcelain at its maximum temperature for a short time should be condemned. It makes the porcelain more brittle and causes the formation of minute bubbles throughout the mass. The porcelain should not be placed in an intensely hot furnace, for it causes a crust to be formed on the surface, which prevents the escape of gas. This gas will seek the point of least resistance, which will be along the margin, and result in the formation of bubbles along the margin of the inlay.

Furnaces.

The three varieties of furnaces used in inlay work are the gas, gasolin and the electric. Gas furnaces have been used with but a moderate degree of success. In order to obtain a sufficient supply of air for proper combustion the use of a bellows or compressed air becomes necessary. The noise produced by the combustion is one of the objectionable features.

Fig. 116A.

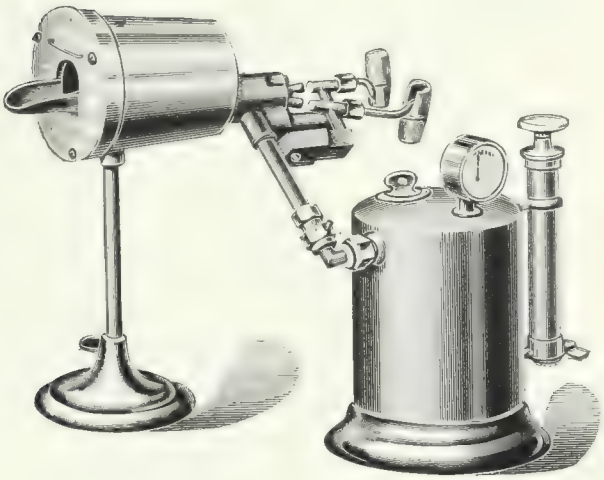


Fig. 116B.

The gasolin furnace is preferable to the gas furnace because it makes less noise, requires no special compressed air outfit and yields a more intense heat. The temperature obtainable in them is sufficient to fuse any of the foundation bodies. The muffles of gas and gasolin furnaces need careful watching, and just as soon as the continuity of the muffle is broken, it is absolutely necessary that a new one be inserted to prevent "gassing" of the porcelain. The two gasolin furnaces which deserve the most consideration are the Brophy (Fig. 116A) and the Turner (Fig. 116B). One of the principal disadvantages of the gasolin furnaces is the lack of convenient means of regulating the heat. Unless the muffle is kept at a high temperature it is hard to fuse high-fusing porcelains, and unless the porcelain is placed slowly into the muffle, its texture will be affected.

Fig. 117.

Since the introduction of the electric furnaces the fusing of porcelain has been much simplified. This style of furnace has the advantage in that the heat is not a product of direct combustion and precludes any possibility of "gassing" the porcelain. The heat is radiated from all sides within the oven. The porcelain can be placed directly into the muffle without previous heating. The current can be turned on gradually until enough heat units required to fire the porcelain have been obtained. The ease and accuracy with which the heat can be controlled is also a great advantage. The furnace is small and its operation is clean and noiseless, and it can be conveniently used in the operating room.

The fusing of porcelain is as exacting as any step in the construction of the inlay. It is difficult to fuse porcelain definitely without some means of measuring the heat and many otherwise good inlays are spoiled in the furnace. Fairly accurate results may be obtained by placing a pellet of pure gold on the slab in the muffle of the furnace, increasing the resistance until the pellet melts, and maintaining the heat on a given button for the desired period.

Pyrometers.

Dr. D. O. M. Le Cron designed a form of pyrometer (Fig. 117) which gives more accurate results than the pure gold test. The device is exceedingly simple and the designer says of it:

"A small cube of soapstone is excavated to resemble an hour glass; in the upper expanded cavity is placed a small spherical mass of an alloy composed of platinum and gold. The relative proportion of the two metals governs the fusing points of the alloy. By varying the proportions the temperature may be graduated to any extent within the limits

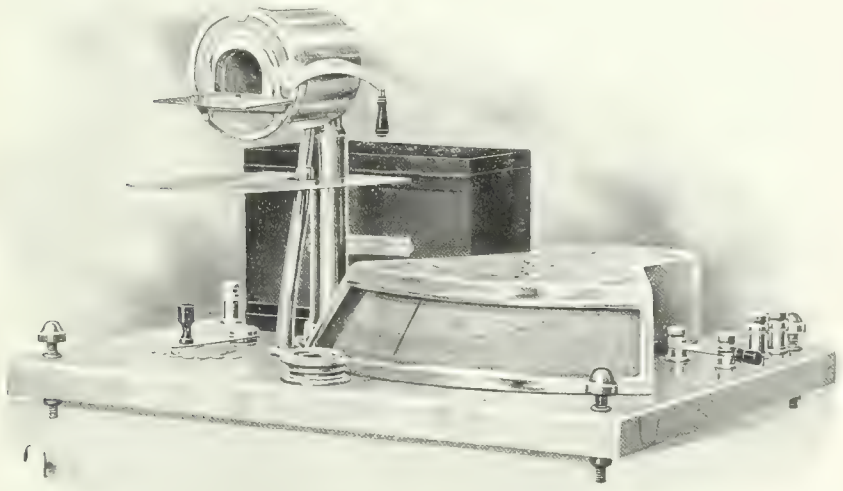


Fig. 118.

desired. The proper temperature of fusing for a given body is matched with a pellet of alloy. The pyrometer is set in the muffle, and when the temperature at which the porcelain fuses has been reached, the little metal ball melts and runs down into the lower chamber." This method makes possible a fair degree of accuracy, provided it is used each time under similar conditions.

Since the introduction of electrical dental pyrometers, the fusing of porcelain has been simplified, and positive results can be obtained. To Dr. W. A. Price, of Cleveland, belongs the credit of placing the first electric dental pyrometer on the market. The pyrometer designed by Dr. Price depends upon the principle of the thermo-pile or the thermo-couple system (Fig. 118).

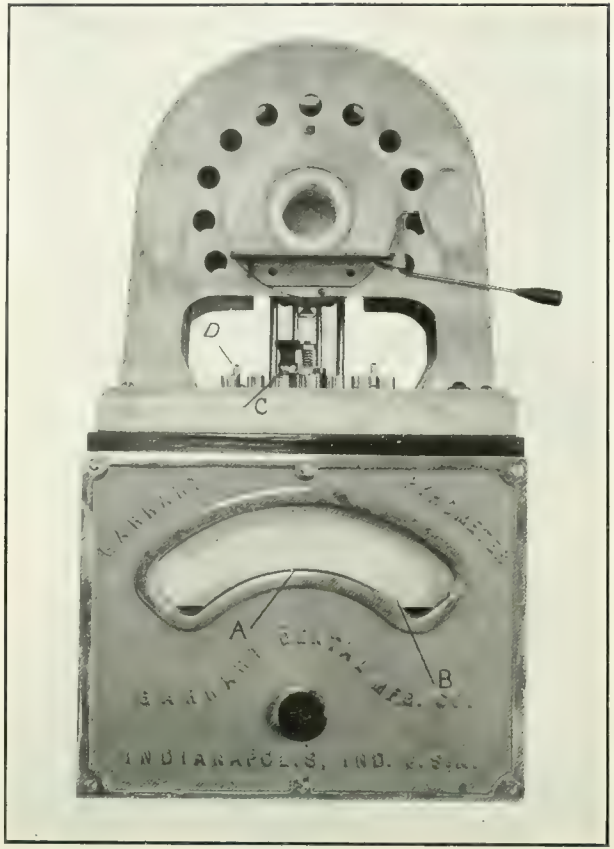


FIG. 119.

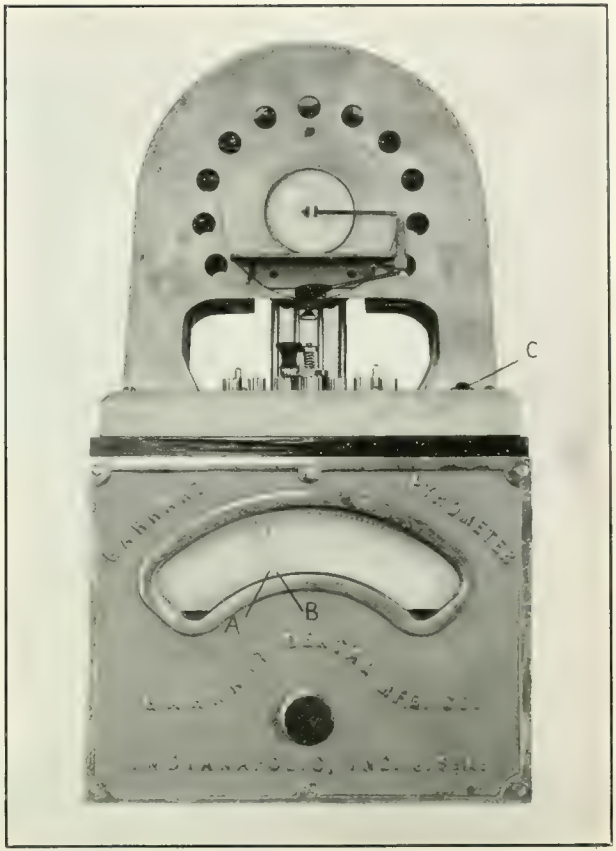


FIG. 120.

The "thermo-couple system" is the one generally used by the manufacturers of dental pyrometers. The pyrometer may be divided into two parts, the first being the "thermo-couple," or portion that is introduced into the muffle of the furnace, and second, the milli-ammeter or millivoltameter that registers the temperature of the muffle. The "thermo-couple" is usually composed of a small spherical shaped mass of rhodium,

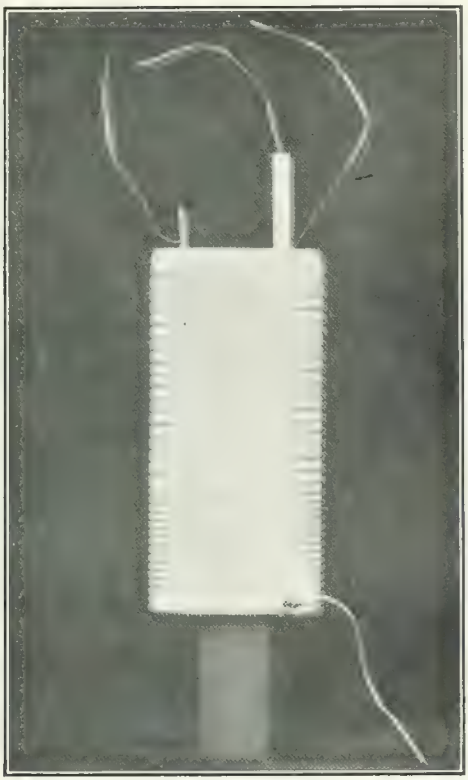


Fig. 121.

to which is attached two heavy platinum lead wires. In some instances two of these elements are used or connected in series in order to secure a greater volume of current for the purpose of actuating the recording instrument. This element is a miniature heat battery, that is, when it is exposed to heat it will generate a feeble current which increases or decreases according to the variations of temperature that takes place within the muffle. This feeble current so generated is in turn measured

by the milli-voltameter. When operated under certain conditions this system is quite accurate. To operate it so that it is perfectly accurate, the wires leading from the "thermo-couple" should be kept cold by artificial refrigeration. If these wires are permitted to heat up, the "thermo-couple" loses in its efficiency to generate the same intensity of current. One other point to bear in mind is the accuracy of the milli-voltameter which must be so designed as to be extremely sensitive in registering

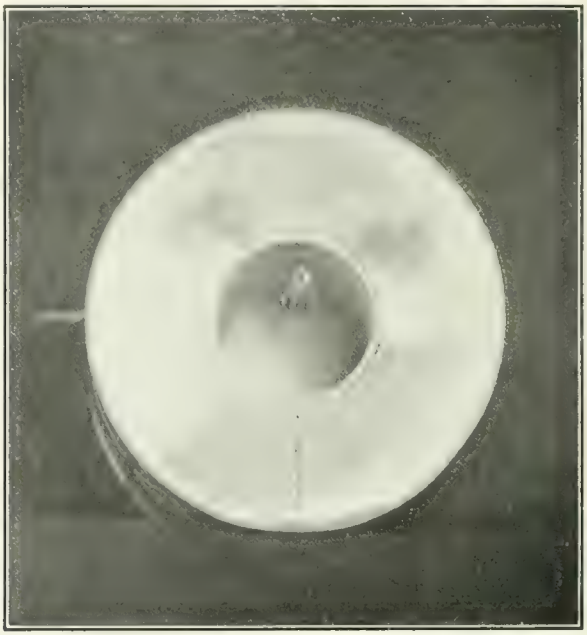


FIG. 122.

every minute variation of current change that takes place in the "thermo-couple." It should be accurately adjusted or standarized at least once a year.

The pyrometer designed by Mr. N. K. Garhart (Fig. 119) operates on an entirely different principle from the "thermo-couple system." The inventor took advantage of a special feature possessed by the "Nernst glower," The "Nernst glower" is a miniature rod that is used for electric lighting and was confined to that use solely by its inventor, Mr. Nernst. This element is made up of the oxids of the rare earths such as are used in the manufacture of Welsbach gas mantels. These earths are fused into two miniature rods which resemble fused porcelain in ap-

pearance. To both ends of these two rods are fused platinum lead wires for conveying the current to the "glower." These glowers have the peculiar property of changing in resistance to conductivity of the current according to the temperature to which they are exposed. To illustrate this point more clearly, the "Nernst glower" is a perfect non-conductor when cold, but when heated it becomes a conductor of the electric current, and its conductivity increases as the temperature to which it is exposed increases. By placing one or more of these glowers in the

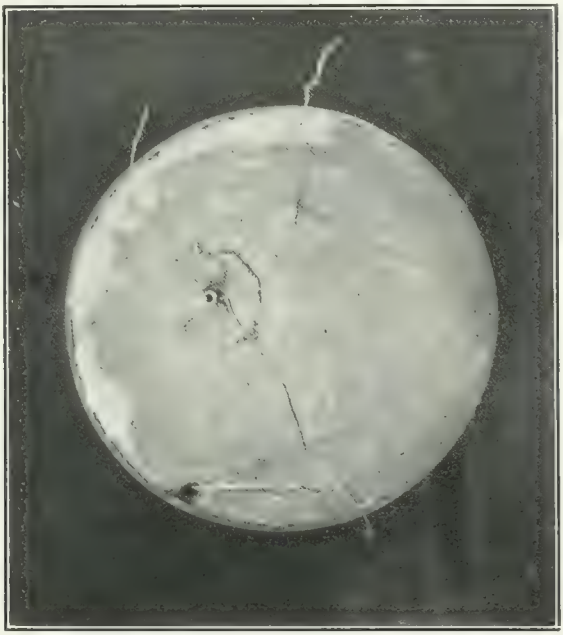


Fig. 123.

muffle (Fig. 122) and connecting them in series with a milli-voltameter which is also in series with a stable low voltage circuit, the heat of the muffle is recorded. The amount of current that is required to actuate the instrument is very small; hence a stable unvarying current supply is secured with three ordinary dry cells. These cells will maintain this form of pyrometer in an accurate condition for a period of at least one year. In connection with this pyrometer there is a means by which the accuracy of the instrument may be instantly tested before each firing. There is interposed in the battery and instrument circuit a resistance coil operated by a small push button switch. By merely pressing on this

switch the pyrometer hand will ascend the scale to a certain reading which indicates the accuracy of the instrument (Fig. 119A). If the reading on the scale shows a falling off it is evident that three new cells should replace the old ones. This test must always be made when the furnace is cold.

The "glower" that is placed within the muffle does not undergo any change, for it conducts only a very feeble current and thus there is practically no element or source of inaccuracy from its use. With every muffle renewal new glowers are supplied, hence the accuracy of this system is fully maintained. Experience in the use of new muffles also has proven that there is no variation in one set of glowers as compared with another. Another strong feature about this system is the fact that a more stable recording instrument is employed.

The inventor devised this style of pyrometer in order to perfect a pyrometer furnace that would be automatic in the fusing of porcelain, for the "thermo-couple" system, he says, is impracticable for this purpose. His furnace is at present the only one that is truly automatic in its working properties, and at the same time scientifically accurate in results.

The muffle construction is decidedly novel and unique. The outer casing is a three-inch seamless brass tubing, which is placed in a steel mold and filled with damp fireclay under hydraulic pressure. The muffle proper is made from a special impervious snow white berline porcelain. It is cylindrical in shape and is grooved on the outside as shown in Fig. 121. This figure also shows the thin shell of chamber mounted on a special mandrel with the wire wound in the grooves. Figs. 122 and 123 show the finished muffle, giving a front and rear view of same. Fig. 123 shows the main resistance wires and the wires leading from the glowers. The most important feature concerning the construction of the muffle lies in the manner by which the inner chamber and platinum wireing are invested in the fireclay or outer chamber. There is a space, approximating about one-quarter of an inch between the platinum wire and the fireclay chamber which is filled with very finely powdered silex. The soft powder permits the wire to expand and contract freely and at the same time removes all danger of contamination of the fireclay affecting it. The front and rear of the muffle are sealed to a depth of three-sixteenths of an inch with fireclay. Another notable feature is winding of the wire about the inner porcelain shell. The coils are nearer together at the front than in the rear (Fig. 121) so as to make the temperature more nearly the same in the front section as that of the rear portion of the muffle.

In the operation of the furnace attention is called to Fig. 119B, which is the secondary hand of the pyrometer section. By turning this

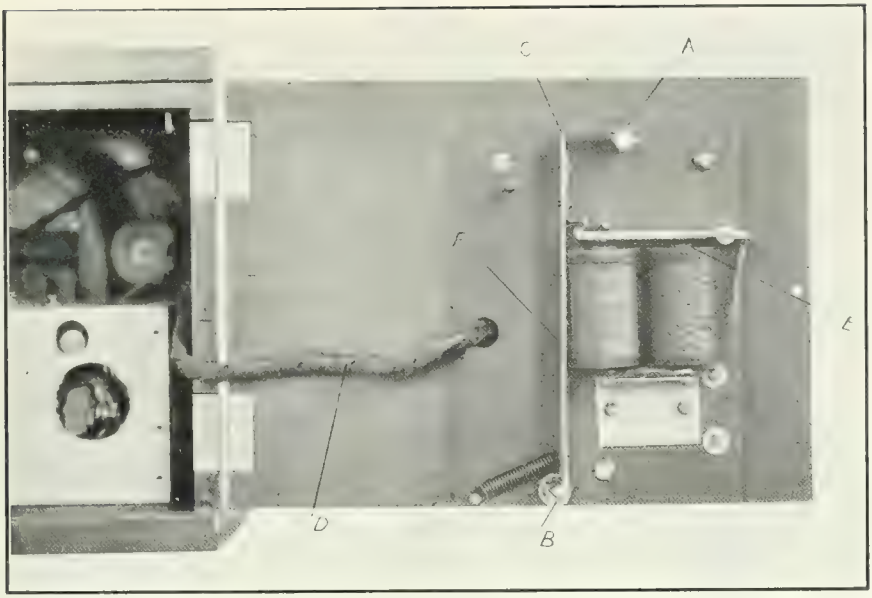


FIG. 124.

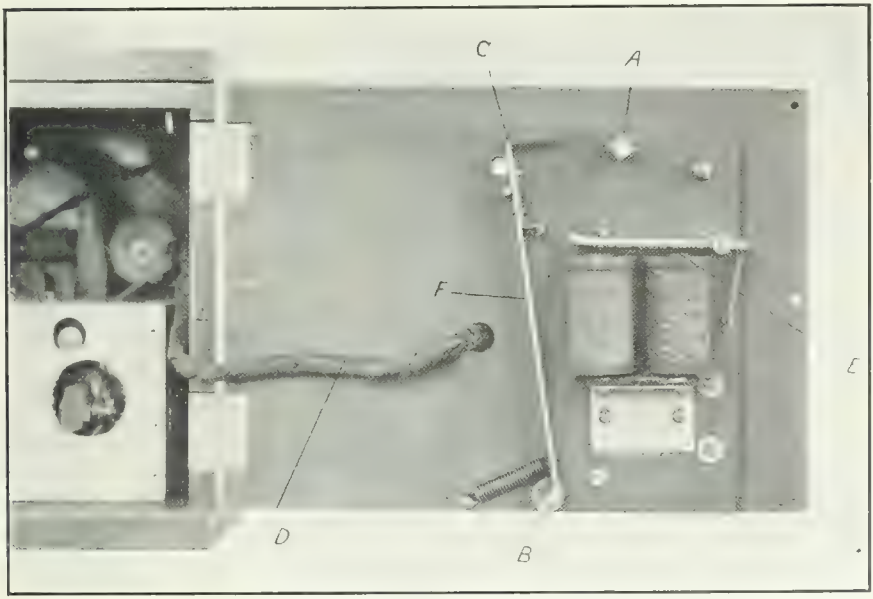


FIG. 125.

hand to any point on the scale (Fig. 120B) the furnace will instantly stop heating when the "recording hand" (Fig. 120A) comes in contact with it. If the operator does not wish to use this "automatic feature" the furnace may be operated as an ordinary pyrometer furnace by moving the "secondary hand" (Fig. 119B) to some point near No. 10 on the scale. The current may be cut out by pressing down on the small button

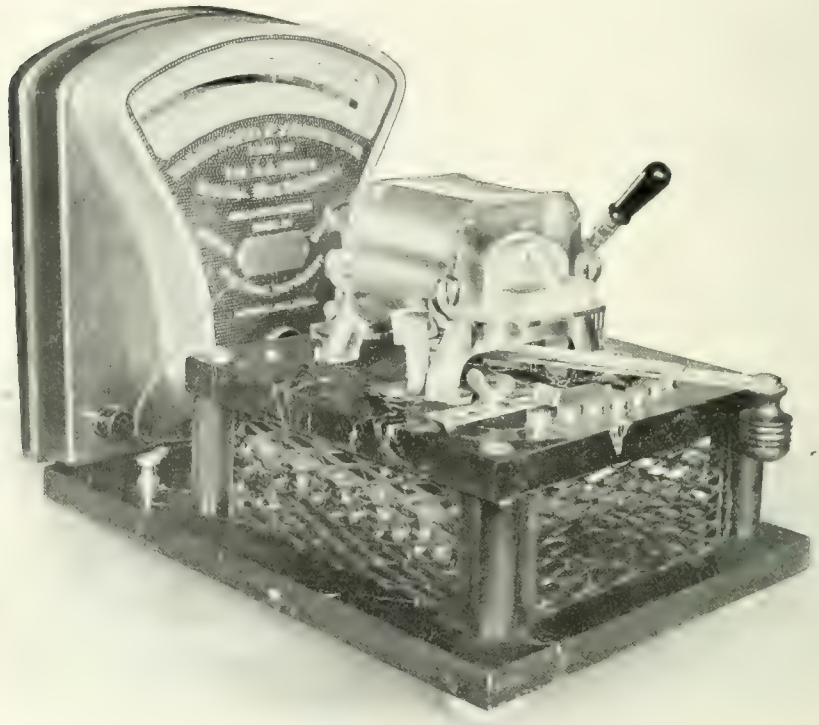


FIG. 126.

switch (Fig. 120C), which is located on the right-hand corner of the marble base on which the furnace is mounted.

The furnace is started by moving the main lever (Fig. 119C) to the left until it touches *stop* "D," at which point it is released and automatically moves over to the second contact. This is the lowest heat contact that the furnace is capable of giving. A notable feature is the fact that the furnace can not be accidentally started while the lever is resting on the higher heat contacts. The operator is always required to move the lever to the extreme left side or until it touches the *stop* "D."

Figs. 124 and 125 show the operation of the magnetic cut-off switch. Fig. 124A shows the switch closed and Fig 125C shows it after the circuit is opened. The terminals of switch are protected with heavy platinum contacts and the breaking of the circuit is accomplished through the magnet E, in an instantaneous manner. D shows the wires leading from main current to the terminals of the magnetic cut-off at A and B. F shows the steel bar, which, when in contact with A, completes the circuit.

Fig. 126 shows the Hammond pyrometer furnace and Fig 128 shows the pyrometer designed by Dr. Marshall Weaver, of Cleveland, and

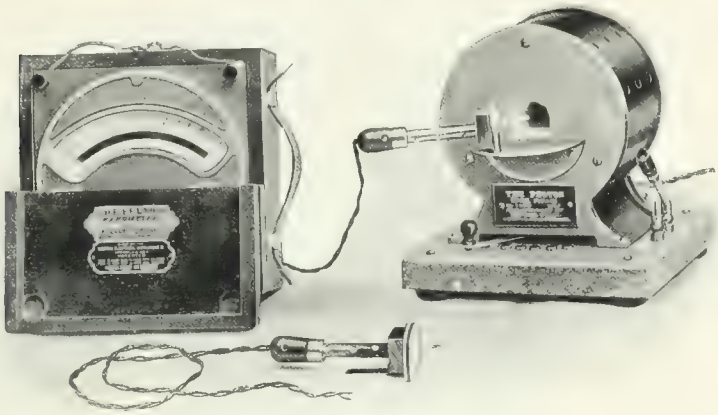


FIG. 127.

attached to the Pelton furnace. This pyrometer has an advantage that it may be attached to any furnace. These pyrometers are constructed with the thermo-couple system. While these instruments record both temperature and resistance on the face of the milli-ammeter, the temperature scale is of no special value in fusing the porcelain. It must be borne in mind that porcelain has no definite fusing point, as a piece of metal has, and the mere fact of heating the furnace up to the degree of heat indicated on the scale for the fusing of a given porcelain will not necessarily cause the porcelain to fuse. Time is a large factor in the fusing of porcelain, and unless sufficient time is given the porcelain will not be properly fused. If, on the other hand, too much time is consumed when the porcelain is heated to the point of high biscuit, it will become over-fused. It is just as well to fuse the porcelain at a given point of resistance on the scale as to fuse it at a given temperature point.

These two pyrometers have the disadvantage of needing to be constantly watched, and many inlays have been spoiled with this style of pyrometer furnace because the heat has been carried beyond the point required to fuse the porcelain, or the inlay is left at the maximum heat required to fuse it for too great a length of time. If this style of pyro-

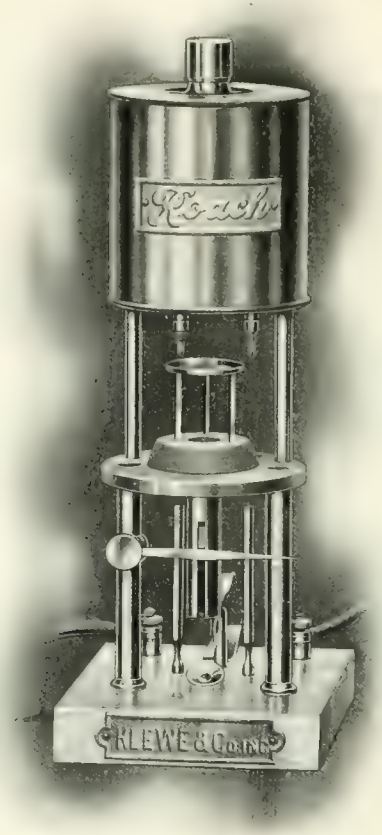


Fig. 128.

meter is used, the operator should pay strict attention to the instrument when the heat becomes sufficient to hard-biscuit the porcelain.

The Roach automatic furnace (Fig. 128) is constructed on a different principle. A small lead plug makes the connection just below the muffle and completes the circuit. When sufficient heat is obtained the plug melts and breaks the circuit. The degree of heat is regulated by the distance the plug is placed from the muffle. A series of figures are

placed on one of the supports, and by raising or lowering the arm, the temperature is changed. The lower the arm is placed the more heat is required to fuse the plug. While this furnace is accurate for low-fusing porcelain it seems to be less reliable for high-fusing porcelain, unless the plugs are made of a higher-fusing metal. The base of the furnace becomes hot when used for high-fusing porcelain; it retains so much heat that the lead plug melts before sufficient heat is obtained to fuse some high-fusing porcelains.

Technique of Fusing Porcelains.

The muffle should first be heated to at least 2,000° F. in order that the fireclay casing may become hot. The lever should be brought back to the first button of the rheostat. When the work is ready to be placed into the muffle the current should be turned off and the muffle permitted to cool until the redness has disappeared. The porcelain should then be placed into the muffle and the current turned on. The heat should be increased gradually. If an electric pyrometer is used the needle should move slowly, and when all the heat is obtained from a given resistance the lever should be moved to the next button. When the needle of the milli-ammeter registers at the proper point for the fusing of a given porcelain the current is shut off. If the Garhart automatic pyrometer is used the secondary hand is set at the point at which the porcelain is to fuse. The rheostat lever is moved gradually until it has reached the button required to fuse the porcelain, after which no further attention is required, for the current is automatically cut out when the pyrometer hand and the secondary hand come in contact. The author has used this automatic furnace more than three thousand times and it has never failed to cut out the current at the proper time.

It must be borne in mind that pyrometer furnaces are not accurate unless they are manipulated under uniform conditions. The following points should be observed in fusing porcelain. Always heat the muffle previous to firing the porcelain. Never place the porcelain in an intensely hot furnace. Heat the porcelain slowly. Run the pyrometer under similar conditions for each firing. Do not try to fuse porcelain and do other things at the same time unless an automatic pyrometer furnace is being used.

A complex inlay should be tried into the cavity before the matrix is removed; for in many instances it is necessary to grind the inlay to proper occlusion. This can be accomplished best by testing with carbon paper and grinding at such points as are indicated by spots on the porcelain. The incisal edge should be ground to proper length and contour. After this necessary grinding the inlay should be thoroughly cleansed and then fired to a high biscuit.

Chapter VIII.

Technique of Finishing and Setting Inlays.

After the fusing process has been completed, the matrix should be removed by gripping it with the lock tweezers and peeling the foil toward the center of the inlay. It may be necessary to catch the matrix at different points in order to loosen it at the margins. If the porcelain and the metal adhere firmly, this adhesion may be partially broken by placing the inlay and matrix in water for a few minutes, and the foil may then be removed more easily. If there were any perforations in the matrix, through which some of the porcelain has flowed, the adhesion will be greatest at these points, and it will be almost impossible to remove the matrix without some method of instrumentation. When these points of adhesion are somewhat distant from the margin the foil may be removed with a small stone or a dull bur; but if such points of contact are along the margin the metal should be removed with an excavator. Unless this is done delicately the inlay may be chipped along the margin. In order to prevent this chipping all scraping should be from the margin toward the center of the inlay. In case it seems inadvisable to remove a small piece of foil at the margin by instrumentation the inlay may be placed in hot *aqua regia* until the foil is dissolved.

Cutting Grooves.

The inlay should be grooved after it has been separated from the matrix. This may be done best with a small diamond disk (Fig. 129), which may be used as a copper disk with carborundum powder after the diamond dust has worn off. The location and depth of the grooves depend upon the size and shape of the inlay. When the inlay is for a cavity on the labial or buccal surface, the groove should extend around its circumference near the base (Fig. 130A). If, however, the inlay is constructed for a simple approximal or approximo-incisal cavity, the groove should be formed along the ridge of the inlay that fits into the cavity (Fig. 131A). It is also advisable to make a groove along the seat extending in a labio-lingual direction. In all cases in which the

inlay is grooved the cavity should be grooved in such a manner that the cement will fill the space made by the two opposite grooves, representing the tenon of a mortise joint. It is not necessary that these grooves be deep, but they should be cut so that the groove on the inlay and the corresponding one in the wall of the cavity will form one channel (Fig. 131B). Any margin of porcelain that may overhang the gingival wall should be removed with fine grit stones, and the surface should be polished with cuttlefish disks before the inlay is set.

FIG. 129.

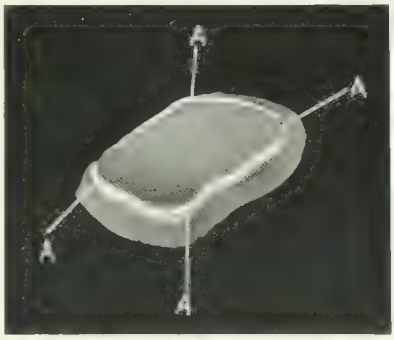


FIG. 130.

Etching. When the inlay has been properly grooved it should be etched with hydrofluoric acid. To do this requires that the margins should be invested in wax (Fig. 132) in such manner that it is impossible for any of the acid to reach them. The investing is accomplished by making a depression in a block of beeswax with a warm spatula and inserting the inlay so that only the cavity surface will be exposed, a result that is best obtained by searing the wax to the porcelain with a hot spatula. The acid is to be applied by dipping a pointed stick into the bottle and placing a drop on the exposed surface of the porcelain, where it should be allowed to remain from three to five minutes. The acid should then be neutralized by a solution of sodium bicarbonate.

It should be borne in mind that hydrofluoric acid is a solvent of both glass and porcelain, and that it must be kept in a wax or gutta percha bottle. This acid attacks living tissue violently, and in case it comes

into contact with the flesh it makes a painful wound. Utmost care should, therefore, be exercised in handling the acid; but if it should get on the hands it should be neutralized *at once* with a solution of sodium bicarbonate.

The acid having been thoroughly neutralized the inlay should be removed from the wax and placed in boiling water for about five minutes. After this it should be thoroughly washed with chloroform to remove any wax that may still adhere to it. It is then to be dried with warm air.

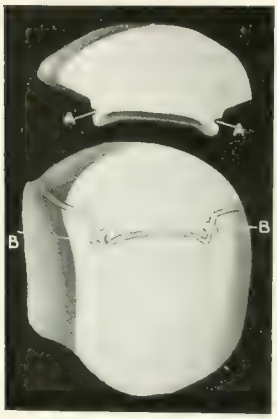


FIG. 131.

FIG. 132.

Setting the Inlay.

If, by judicious use of absorbents, the cavity can not be kept dry, the rubber dam should now be adjusted. It has been found that most cavities in upper teeth can be kept dry by placing a small napkin between the teeth and a roll of absorbent cotton between the lips or cheeks and the gums. After the cavity has been thoroughly dried it is then grooved with a small inverted cone bur. It should now be wiped with a pellet of cotton saturated with chloroform, and after this has been done it should be thoroughly dried with warm air.

The ideal cement for setting inlays would be translucent and very adhesive. But since it is necessary to use an opaque cement, the ideal kind not yet having been produced, the whitest that can be obtained is probably the best for setting all large inlays. When inlays are constructed of a monochromatic porcelain and are slightly lighter than the tooth, a cement that is the same color as the porcelain, but of a lighter hue, is the best for setting them, because the rays that are transmitted through the porcelain are not so freely absorbed by the cement, but are

reflected to the surface with practically no change of color other than intensifying it. Pure white would be the best opaque cement for setting all simple approximal and approximo-incisal inlays constructed of a multi-colored porcelain, because white bodies do not absorb light, but reflect it. The same rays that are reflected to the cement would then be reflected to the surface for the reason that white has greater reflective power than any of the colors. Unfortunately the manufacturers are unable to produce a pure white cement. We can not, therefore, entirely overcome the change of color caused by the cement's dimly reflecting and partially absorbing the transmitted rays.

In order to obtain the greatest adhesiveness the cement powder and liquid should be mixed in definite proportions, and they should be spatulated thoroughly. The consistency of the cement is to be determined by its adhesiveness, and the operator should familiarize himself with the proper proportions of cement and liquid to yield the greatest adhesive quality. A large glass slab and a bone, ivory, glass or agate spatula should be used for mixing. The powder and liquid should be placed on the slab, each in a separate position, so that a small portion of the powder may be easily incorporated with the liquid. Moreover, small portions of the powder are to be added, and the mass should be manipulated as each addition is made, until there is the "feel" and appearance of complete mixture. After sufficient powder has been worked into the liquid, the mass should be spatulated thoroughly.

A thin film of cement should now be spread over the walls and margins of the cavity with a small bone spatula or a wooden point. After this a thin film is to be placed on the etched surface of the inlay, which should then be forced into position. If the cavity is on the labial or buccal surface the inlay should be pressed into place with soft wood or rubber, and then forced into absolute relation by tying a silk ligature around the tooth, making a surgeon's knot on the inlay. At this point in the operation care should be taken not to exert sufficient pressure to fracture the inlay. If the case is for a simple approximal or an approximo-incisal cavity the inlay should be inserted with pliers or the fingers, and then forced into place with a strip of thin linen tape. The force should be exerted in such manner that the inlay will be rocked into position. After the surplus cement has been expressed the inlay is to be forced into its place by exerting constant pressure with the tape. If a hydraulic cement has been used the surplus should be moistened with water. If a non-hydraulic cement has been used it should be kept dry for ten or fifteen minutes, after which time remove the surplus and paint the margins with sandrac varnish.

Finishing the inlay should be accomplished as a subsequent operation, which should not be attempted until the cement has thoroughly hardened. Very little finishing will be required if proper care is exercised in applying the porcelain. All margins of porcelain overhanging the enamel are to be removed with fine grit stones (Fig. 5A), and the inlay should then be polished with cuttlefish disks and Arkansas stones (Fig. 5C). These stones should be kept thoroughly moistened and used with a moderate degree of pressure.

Discarded
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